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UNIVERSITY OF ALBERTA

Methane Occurrence and Dispersion in Large Auxiliary Ventilated Mine Roadways

by

© Raymond Sogna Suglo

A THESIS SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND
RESEARCH IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS OF THE
DEGREE OF MASTER OF SCIENCE

in

Mining Engineering

Department of Mining, Metallurgical and Petroleum Engineering

EDMONTON, ALBERTA

SPRING 1995

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled:

Methane Occurrence and Dispersion in Large Auxiliary Ventilated Mine Roadways

submitted by Raymond Sogna Suglo in partial fulfillment of the requirements for the degree of the Master of Science in Mining Engineering.

Prof. Josef Szymanski

Prof. Ian R. Muirhead (Supervisor)

Prof. Jerry M. Whiting

Prof. J. Doug Dale

Date: 10 April 1995

DEDICATION

This work is dedicated, first and foremost, to the Almighty God for his great love and protection throughout my life. To him who takes care of the needs of both the elephant and the ant, be praise and glory!

Secondly, it is dedicated to my wife, Justina, and to my children, Lambert, Patience and Jennifer, for their constant prayers, love and understanding throughout my two-years' absence from them. May they be richly blessed by the Lord the Supreme Creator.

ABSTRACT

Mining at greater depths and the mechanization of most underground mining operations have led to the production of higher concentrations of gases and other contaminants. Potentially dangerous conditions often occur at distant development faces where coal is being cut due to the inability of the main ventilation systems to dilute the methane concentrations to safe levels. Auxiliary ventilation systems are employed in development headings to control methane gas concentrations within safe limits.

The results of this study on auxiliary ventilation systems in selected coal mines in North America, show that distances from the end of the primary intake ducting to the face not exceeding 10 m will ensure safe methane concentration levels (≤ 0.4%) within headings, faster purging times of the methane concentration at the face (≤ 8 min.) and efficiencies of the auxiliary ventilation systems above 45%; measurements made in some headings indicated the likelihood of methane layering.

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I want to thank my Supervisor, Professor Ian R. Muirhead, for his unparalleled love, patience, understanding and readiness to assist, guide and motivate me throughout this work. At a time when all seemed lost with problems arranging visits to operating coal mines, he brought his management expertise into play by his ability to successfully arrange for me to visit some of the operating mines, to collect data and conduct on-site measurements. By this action, he ably salvaged me from an imminent disaster and has seen me through one of the most turbulent periods in my life. I must say that I am highly indebted to him for all that he has done for me which has enabled me to reach this stage in my work.

Special and heartfelt thanks to Professor and Mrs. Jerry Whiting for all their encouragement, innumerable material and moral support but above all for their priceless companionship not only in my studies but also throughout my stay in Edmonton. I certainly cannot find words to thank them for all that they have individually and collectively done for me.

I gratefully acknowledge the financial and logistical support from the Natural Scientific and Engineering Research Council (NSERC) in this research which enabled me to visit the operating coal mines in Canada to collect data.

I also express my thanks and deep-seated appreciation to the managements of all the operating coal mining companies who responded to my questionnaire and provided me with the much-needed data and information about their operations which has brought this work to fruition. Special and heartfelt thanks go to the hardworking researchers and

engineers at the Canada Centre for Mineral and Energy Technology, CBCRL, Sydney for placing their equipment and priceless expertise at my disposal during this study. Mr. Gary Bonnell was particularly of tremendous help both professionally and as a tourist guide. For reasons of confidentiality, I sincerely thank the friendly and hardworking Managements and staff of all the mines visited across Canada for their assistance in this work. Without their help, this work would not have reached this stage.

Finally to all the Professors, friendly staff and students of the Department of Mining, Metallurgical and Petroleum Engineering, friends (particularly Trevor Munk who has been of enormous assistance to me) and my room-mates, who in diverse ways assisted and encouraged me in this work and made my stay in Edmonton extremely interesting and eventful, I say a big thank you.

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Chapter One

INTRODUCTION

1.1 BACKGROUND

Ventilation systems are employed to create safe and acceptable working conditions for men and equipment in underground mines. The problems in mine ventilation systems continue to escalate with increasing mining depths and mechanization as well as with the different types of strata encountered underground. As mining depletes near-surface reserves, there is the need to go deeper to evaluate, develop and to open up new reserves for mining. Consequently, most working places and faces are continually being advanced away from the shafts and the air stream from the main ventilation systems reaching these workings is often insufficient, ineffective or inadequate [1].

As most of the gas emissions and contaminant levels are higher in areas where new coal or rock is being worked, gas concentrations and contaminant levels could easily reach high, explosive and unacceptable levels within a very short time if not properly diluted and dispersed by the mine ventilation systems.

Auxiliary ventilation methods are employed to supply fresh, uncontaminated (and in some cases conditioned) air in sufficient quantities to such dead-end working places to control gas levels and create safe working environments there. In underground coal mines, methane gas and coal dust are the main contaminants encountered. Methane gas, which is very explosive at concentrations ranging from 5 to 15% by volume in air [2], has to be closely monitored at all times in all active workings. Over 10% of all underground fatalities in coal mines have been attributed to methane gas explosions alone [3]. As a result of the huge losses in lives, equipment and property in these explosions, mine managements have employed various ventilation systems to control and maintain the concentrations of methane gas at approved levels well below the lower explosive limit of 5% in air and to create safe working conditions as required by Federal, State or Provincial Government laws [1]. It was found necessary to study the mode of occurrence of methane gas in large coal mine roadways and assess the effectiveness of auxiliary ventilation systems in development drivages in the dispersion of methane gas. These workings were chosen for study because they are often of considerable length and distance from the existing main ventilation air streams; are advanced at faster rates giving rise to greater methane emission rates and contain more mining equipment concentrated in workings which have limited cross-sectional area. Consequently, methane concentrations in such areas can easily reach high levels within a very short time.

The term dispersion, as used in this study, refers to the control and dilution of methane concentration within safe levels and its removal from mine workings. Also large auxiliary ventilated mine roadways in this context refer to all mine development headings with cross-sectional areas greater than 10 m^2.

1.2 OBJECTIVES

The objectives of this study were to:

1) evaluate the types of auxiliary ventilation systems which are presently employed in selected operating coal mines in North America.

2) assess the methods employed by the mines in dealing with methane gas and other noxious and explosive gases in mine roadways or development headings.

3) investigate the mechanisms by which methane gas is stored in the coal and surrounding strata, is emitted into the mine openings and how it collects in the roof and other high elevations in mine development headings.

4) determine how the existing ventilation systems affect the layering structure/mechanism of methane gas in development headings.

5) determine how methane gas accumulations and stratified layers can be safely diluted and dispersed by the auxiliary ventilation systems.

6) identify how the existing auxiliary ventilation systems can be improved or modified to prevent the possible accumulation and/or layering of methane and to achieve its dilution to safe levels and safe removal from the mine workings.

7) conduct a detailed analysis of the various auxiliary ventilation systems to assess their efficiencies and effectiveness in controlling methane gas in roadways.

1.3 METHODOLOGY

This study was primarily concerned with auxiliary ventilation methods employed in coal mines in North America to create safe working environments and to meet various Provincial, State and Federal laws on safety and health in the mines.

It covered all aspects of environmental monitoring in auxiliary ventilated mine roadways and involved pressure, volume, temperature measurements of the mine air as well as the monitoring of methane concentrations in some selected operating development headings by means of continuous methane measuring instruments (CSEs) and handheld methanometers. Studies were conducted purely on the existing setups of the auxiliary ventilation systems of the mines. Due to the high costs that would result in interruptions to the mine operations, no attempt was made to alter or modify any of the systems for experimentation. Due to the limited number of adequate and reliable continuous methane monitoring instruments available, it was not possible to monitor the concentrations of methane at more than two stations simultaneously. Where necessary, handheld methanometers were used to monitor methane concentrations at intermediate locations in the headings.

All analysis and calculations were based solely on the information gathered from either the questionnaires circulated to operating coal mines or from field measurements conducted during mine visits.

Although very much related to methane as a main contaminant in coal mines, coal dust is not treated in this study. Also, the work does not cover the main ventilation methods employed in the mines, the methods employed in dealing with mine dust and other atmospheric contaminants encountered underground or sudden outbursts of methane gas.

Chapter Two

MINE GASES

2.1 ATMOSPHERIC AIR

Atmospheric air consists basically of Oxygen, Nitrogen, Carbon Dioxide, Argon and other rare gases and some amount of water vapor (ranging from a fraction of 1% up to 6%) [4]. These constitute the natural air on the surface of the earth. Table 2 - 1 gives the chemical composition of atmospheric air at sea level.

Table 2 - 1 Chemical Composition of Atmospheric Air (at sea level).

Gas	% by Volume	% by Weight
Oxygen (O_2)	20.95	23.13
Carbon Dioxide (CO_2)	0.03	0.05
Nitrogen (N_2)	78.09	75.55
Argon & other Rare gases	0.93	1.27

Source: Hartman (1982)

2.2 MINE AIR

Mine air, which is the air found in underground workings, comprises three main components which are atmospheric air, noxious or explosive gases and dead air. Mine gases either occur naturally or artificially.

Fig. 2 - 1 is a schematic diagram of the main components of mine air and Table 2 - 2 gives the maximum allowable concentrations of mine gases [1, 5].

Toxic gases are those that are dangerous to the human body if breathed in sufficient concentrations for a sufficient time. They may be asphyxiating, irritating or poisonous to human or animal tissues. Asphyxiating gases may be simple or chemical [4]. Simple asphyxiating gases such as carbon dioxide, nitrogen and methane have no specific toxic effect but tend to exclude oxygen from the lungs. High methane emissions involve risks of suffocation and explosion.

Carbon monoxide is a typical chemical asphyxiating gas, as its higher affinity for the hemoglobin of the blood (*up to 250 times that of oxygen*) makes it combine readily with the hemoglobin thus suppressing the oxygen carrying capacity of the blood.

Irritating gases such as nitric oxide, nitrogen dioxide, hydrogen sulphide, partially oxidized hydrocarbons (like aldehydes) and sulphur dioxide [4] induce inflammation in the sensory organs or tissues of the body such as the skin, the eyes and membranes of the respiratory tract when they come into contact with them.

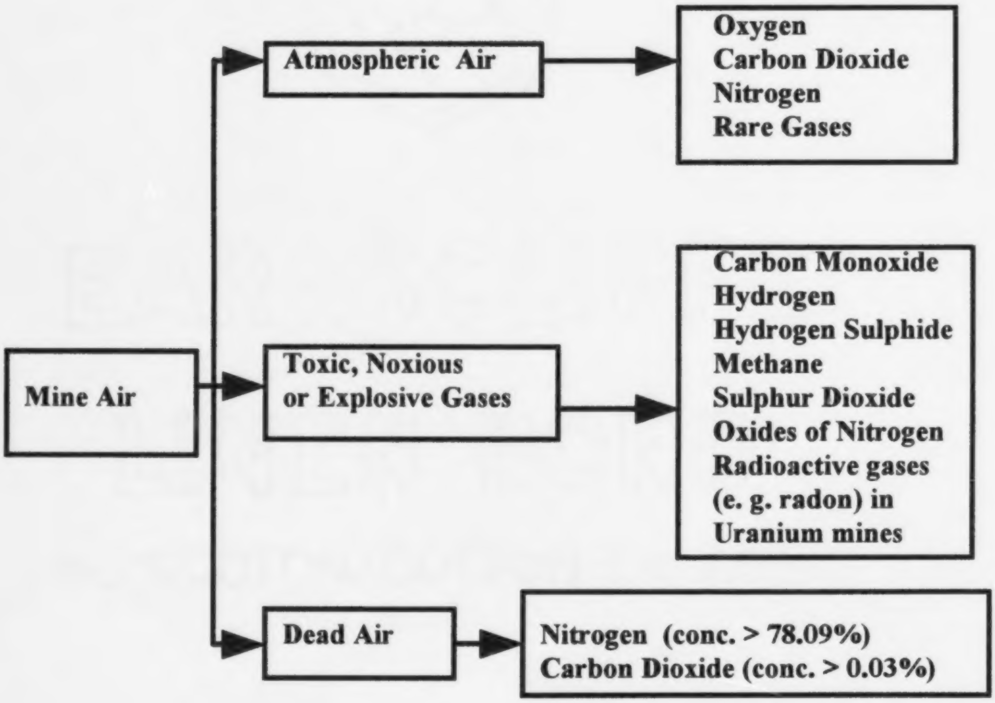

Atmospheric Air
Oxygen
Carbon Dioxide
Nitrogen
Rare Gases
Mine Air
Toxic, Noxious or Explosive Gases
Carbon Monoxide
Hydrogen
Hydrogen Sulphide
Methane
Sulphur Dioxide
Oxides of Nitrogen
Radioactive gases (e. g. radon) in Uranium mines
Dead Air
Nitrogen (conc. > 78.09%)
Carbon Dioxide (conc. > 0.03%)

Fig. 2 - 1 **Schematic Diagram of Main Components of Mine Air**

Gases like nitric oxide, hydrogen sulphide and sulphur dioxide are not only irritant but also very poisonous and generally destroy the tissues with which they come into contact.

Explosive gases are those which in sufficient concentrations in air and under favorable conditions can be easily ignited by sparks, flames or any source of heat. Methane, carbon monoxide, hydrogen and hydrogen sulphide gases are explosive within certain ranges of their concentrations in air (Table 2 - 2).

Table 2 - 2 Maximum Allowable Concentrations of Mine Gases

Gas	**Specific Gravity (air = 1)**	**Maximum Allowable Concentration (MAC) (%)**	**Fatal Point (Explosive Limit) (%)**
Hydrogen (H_2)	0.07	0.8	(4 - 74%)
Methane (CH_4)	0.55	1.0 or 1.25	(5 - 15%)
Nitrogen (N_2)	0.97	78.9	-
Carbon Monoxide (CO)	0.97	0.005 (50 ppm)	0.04 (12.5 - 74.2%)
Oxygen (O_2)	1.11	19.5 (minimum)	6 (minimum)
Hydrogen Sulphide (H_2S)	1.19	0.001 (10 ppm)	0.1 (4 - 44%)
Carbon Dioxide (CO_2)	1.53	0.5	1.5
Nitrogen Oxides (NO_x)	1.59	0.0025 - 0.0035 (25 - 35 ppm)	0.005
Sulphur Dioxide (SO_2)	2.26	0.0005 (5 ppm)	0.1
Radon	7.67	1 WL*	-
Ethane (C_2H_6)	1.05	0.3	(3 - 12.5)
Propane (C_2H_8)	1.55	0.4	(2.1 - 9.35)

Source: Anon. (1980)

{* 1 WL = *Working Level (where 1 WL is defined as the concentration of radon-daughter products in a liter of air that will yield 1.3 × 10^5 million electron volts (MEV) of alpha energy in decaying through radium C')*}

Toxic, poisonous or explosive gases originate from the strata being mined, from the method of mining such as cutting, blasting and other mine machinery employed underground or from unscheduled occurrences like mine fires [1, 6].

Dead air (*sometimes referred to as blackdamp*) comprises carbon dioxide and nitrogen gases in quantities in excess of their normal concentrations in atmospheric air.

Of all the gases in mine air only oxygen supports life and combustion.

2.3 METHANE GAS

Methane gas, the main contaminating gas found in coal mines, is a colorless, odorless, tasteless gas which is highly explosive at concentrations ranging from 5 to 15% in air. The maximum explosibility of methane occurs at 9.6% by volume concentration [2]. However, the explosive limits are generally altered if the mixture contains higher rank hydrocarbons such as ethane, propane, etc., resulting in the widening of the range of explosibility [7]. It has a specific gravity of 0.55 relative to air and is therefore commonly found in the roofs and other high elevations of mine workings.

When mixed with other gases it is commonly referred to as firedamp. Firedamp comprises methane gas (~95%) and small quantities of carbon dioxide, nitrogen, hydrogen sulphide, carbon monoxide and some hydrogen. It may also contain traces of heavier gases of the paraffin series (ethane, propane, butane, etc.) but in special deposits which are close to natural gas fields, oil bearing shales or sands, the percentage of these paraffin gases could be as high as 30% [7].

Methane is a product of the coalification of coal [8]. The very large quantities of methane generally released during the working of coal seams are a pointer to the fact that the gas is stored in coal and its associated strata over a very long time [9]. While generally thought of in relationship to coal and other carbonaceous rocks, methane gas is also associated with other minerals which include apatite, arsenic, copper, diamond, gold, iron, trona, potash, limestone, oil shale and salt mines; with rocks types such as limestones, granites, gneisses, mudstones, pegmatites, shales and quartzites [1,10] as these rocks or the surrounding strata contain some carbonaceous material. The coalification process is shown schematically in Figure 2 - 2.

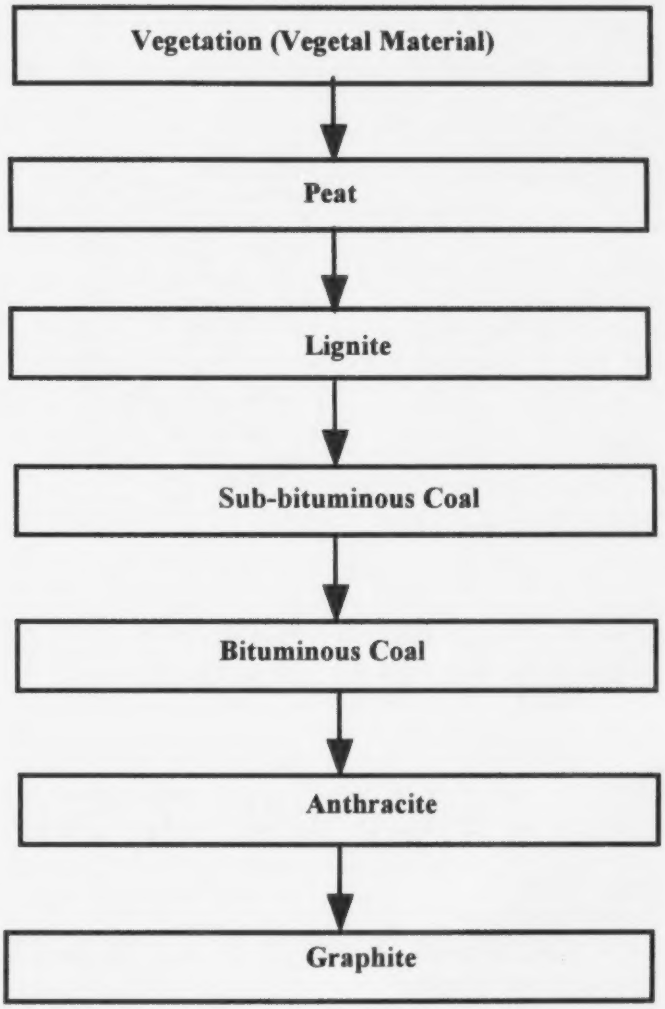

Vegetation (Vegetal Material)
Peat
Lignite
Sub-bituminous Coal
Bituminous Coal
Anthracite
Graphite

Fig. 2 - 2 Coalification Process of Coal

The peat forming process involves biochemical reactions (diagenesis), bituminous and higher rank coal pass through a geochemical (thermogenic or catagenic) stage [8]. The coalification process from peat through anthracite generates large volumes of methane gas together with some small amounts of carbon dioxide and nitrogen. Up to 38 m^3/tonne

(1350 ft^3/ton) of biogenic methane could be generated from wood to low rank lignite while from high volatile bituminous to anthracite rank could generate in excess of 283 m^3/tonne (10,000 ft^3/ton) of methane gas [11]. Depending on the conditions, nature of the strata and depth below surface under which the methane is produced, large amounts may be lost to the atmosphere. However, some of the methane generated is stored in the coal beds by the process of sorption [2, 8].

The process of sorption is sub-divided into four classes [2] as Absorption, Adsorption, Persorption and Chemisorption. Figure 2 - 3 is a schematic diagram of the classes in the sorption process.

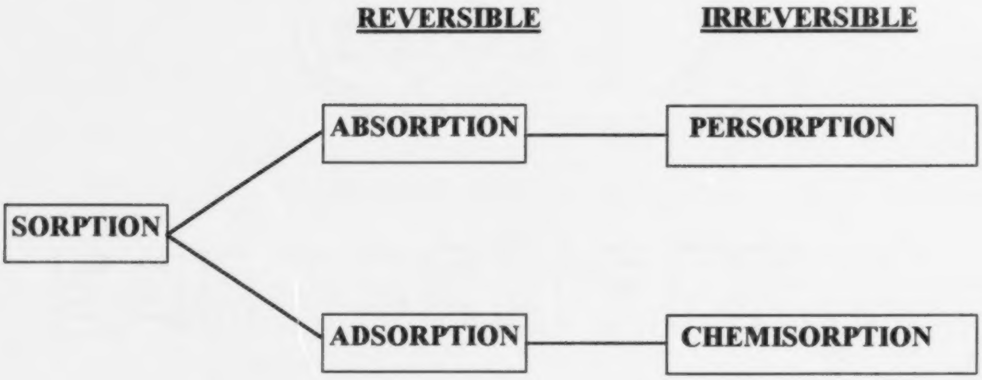


Fig. 2 - 3 Schematic Diagram of Classes in Sorption Process

(Source: Curl, 1978)

Absorption describes a uniform penetration of one substance into the molecular structure of another. Adsorption is the surface effect whereby one substance is physically held to the surface of another. Persorption, on the other hand, is an extremely effective but irreversible absorption of a gas by a solid with the formation of an almost molecular mixture of two substances. Chemisorption is an irreversible adsorption process where the substance is held to a surface by chemical force. As methane gas is not re-generated from the processes of chemisorption and persorption, they are not relevant when considering methane and coal in the context of methane gas prediction in coal mines [2]. However the differences between adsorption and absorption are vital in the prediction of methane gas from coal seams.

Methane is retained or stored in coal in two different ways [2, 12, 13, 14]:

1. As free gas compressed in the pores, fissures, cleats and fractures which are almost always present in the coal.
2. As adsorbed gas on the microscopic surfaces of coal as well as in the micropores.

At very high pressures, methane dissolves to a considerable extent in the free water that may exist in the cleats and fractures of a coal seam [6]. When this water enters the mine openings at lower pressures, the dissolved gas is released from the water into the adjacent air.

Methane exists as free gas in the pore spaces and fissures in coal at equilibrium with the adsorbed gas on the surfaces of the same pores and fissures. There is a constant interchange of molecules between the free gas and the adsorbed gas phase [2].

2.3.1 Free Gas

The amount of free gas in the pores, fractures, cleats and joints of a coal seam may be calculated with the equation [4, 7]:

$$C_v = \phi \frac{P}{P_o} \times \frac{273}{T} \quad \text{m}^3/\text{t} \qquad (2 - 1)$$

where C_v = free gas in pores, m^3/t

ϕ = rock porosity, m^3/t

P = absolute pressure of gas, kPa

P_o = absolute atmospheric pressure (101.3 kPa)

T = absolute temperature, K

2.3.2 Adsorbed Gas

By the process of adsorption large volumes of methane gas are retained on the surfaces of the coal [8]. The process of adsorption is a reversible, physical phenomenon (*the reverse form of adsorption being desorption*). At moderate pressures, the amount of adsorbed gas may be described by Langmuir's equation [4, 7] of the type:

$$C_p = C\left(\frac{KP}{1+KP}\right) \qquad (2 - 2)$$

where C_p = Quantity of gas adsorbed at a pressure P, m^3/t

P = absolute gas pressure, kPa

C = Langmuir's constant representing the quantity of methane gas adsorbed as pressure → ∞, m^3/tonne

K = Langmuir's constant with dimensions of (1/P)

The Langmuir constants C and K are dependent upon the nature of the gas, moisture content, temperature, the rank of the coal and the nature of the adsorbent surface [4].

Fig. 2 - 4 shows that at the same equilibrium pressure, the quantity of gas adsorbed decreases with increasing temperature and is dependent on the type of coal [2]. The nature of the gas is known to play some role in the adsorption process. At a given partial pressure and temperature, carbon dioxide is much more readily adsorbed than methane which in turn is more readily adsorbed than nitrogen. Fig. 2 - 5 shows the variation of methane adsorption with coal rank while Fig. 2 - 6 shows that at the same equilibrium pressure, the quantity of gas adsorbed decreases with increasing temperature depending on the type of coal [7]. The adsorption capacity of coal is highly dependent on the moisture content as expressed in the following equation [7, 12]:

$$\frac{Q_w}{Q_d} = \frac{1}{1+0.31\gamma} \qquad (2 - 3)$$

where Q_w = gas content of moist coal, m^3/tonne

Q_d = gas content of dry coal, m^3/tonne

γ = moisture content, %

Fig. 2 - 7 shows the influence of moisture content on the adsorption of methane on coal.

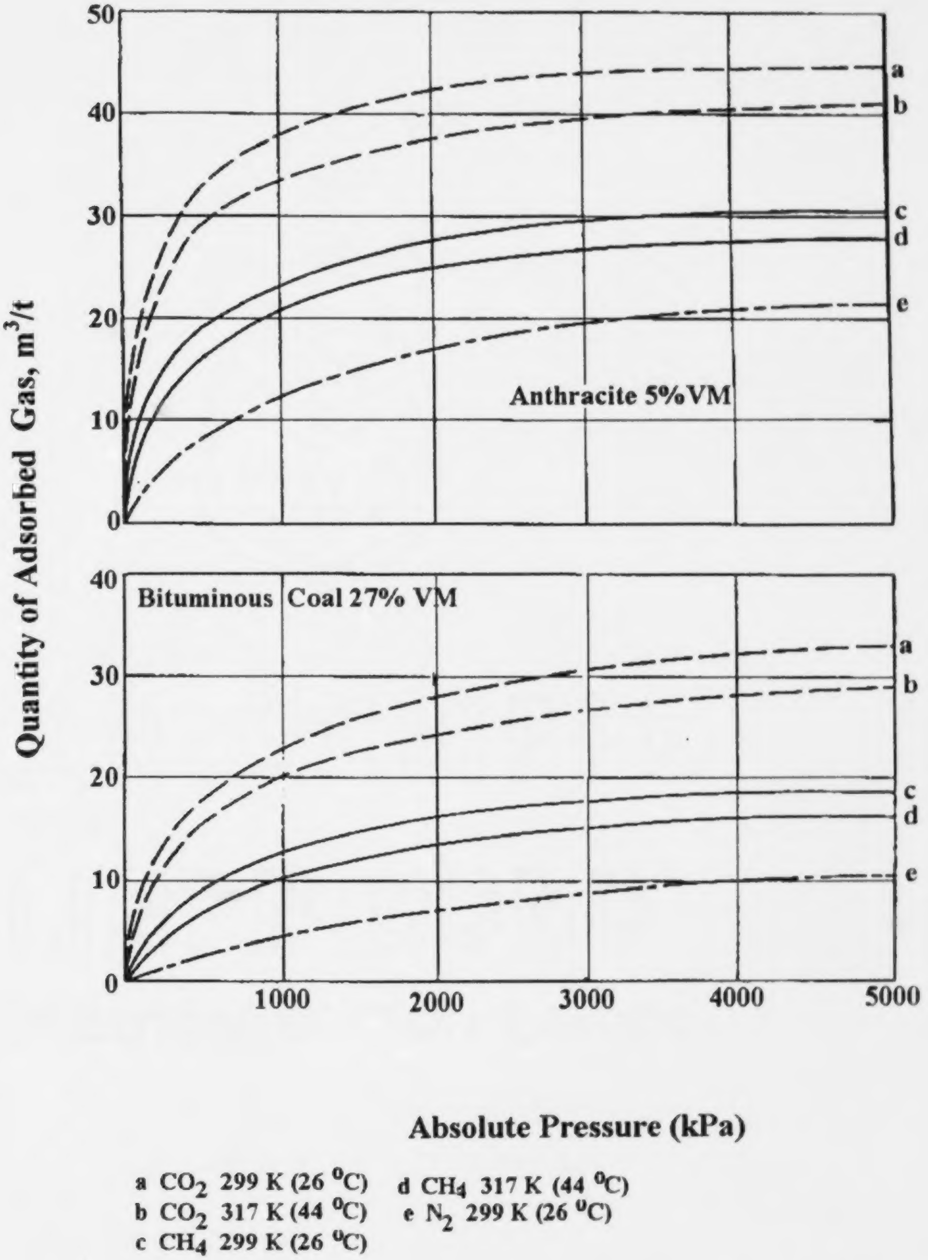


Fig. 2 - 4 **Two Examples of Adsorption Isotherms (Coal dry, ash free)**

Source: Curl (1978)

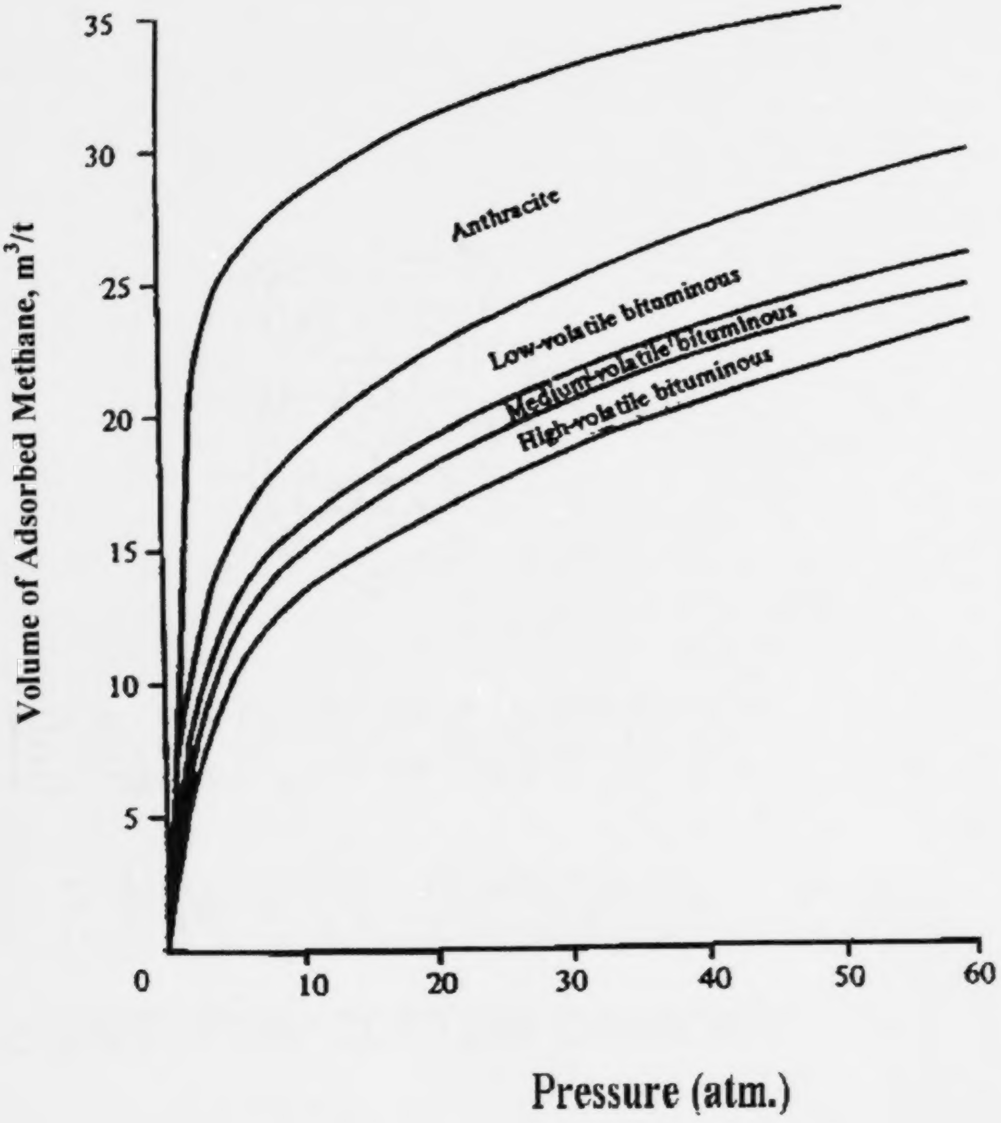


Fig. 2 - 5 Variation of Methane Isotherm with Coal Rank at 0°C

Source: Curl (1978)

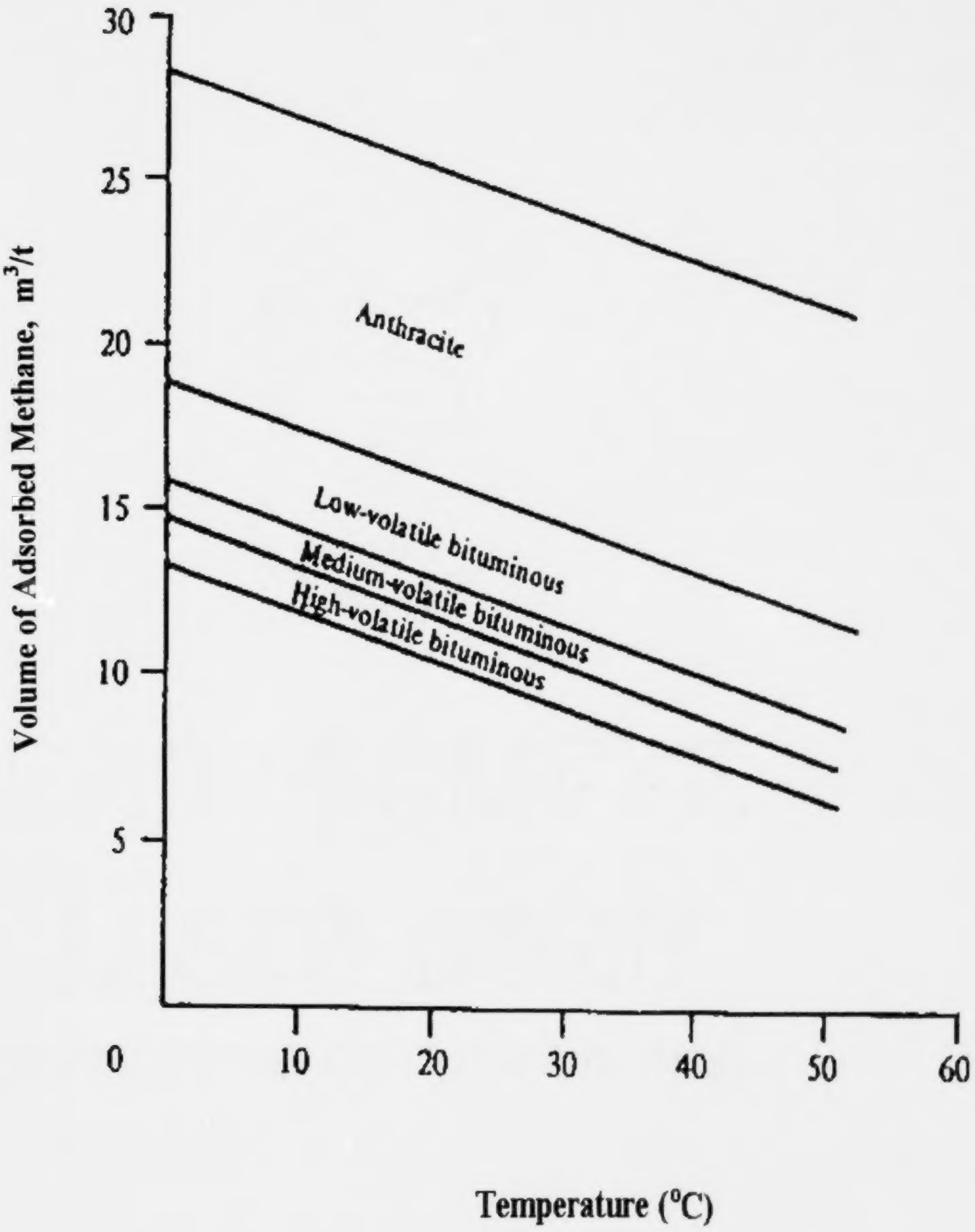


Fig. 2 - 6 **Variation of Adsorption Capacity with Temperature and rank at 10 Atmospheres.** **[Source: Curl, (1978)]**

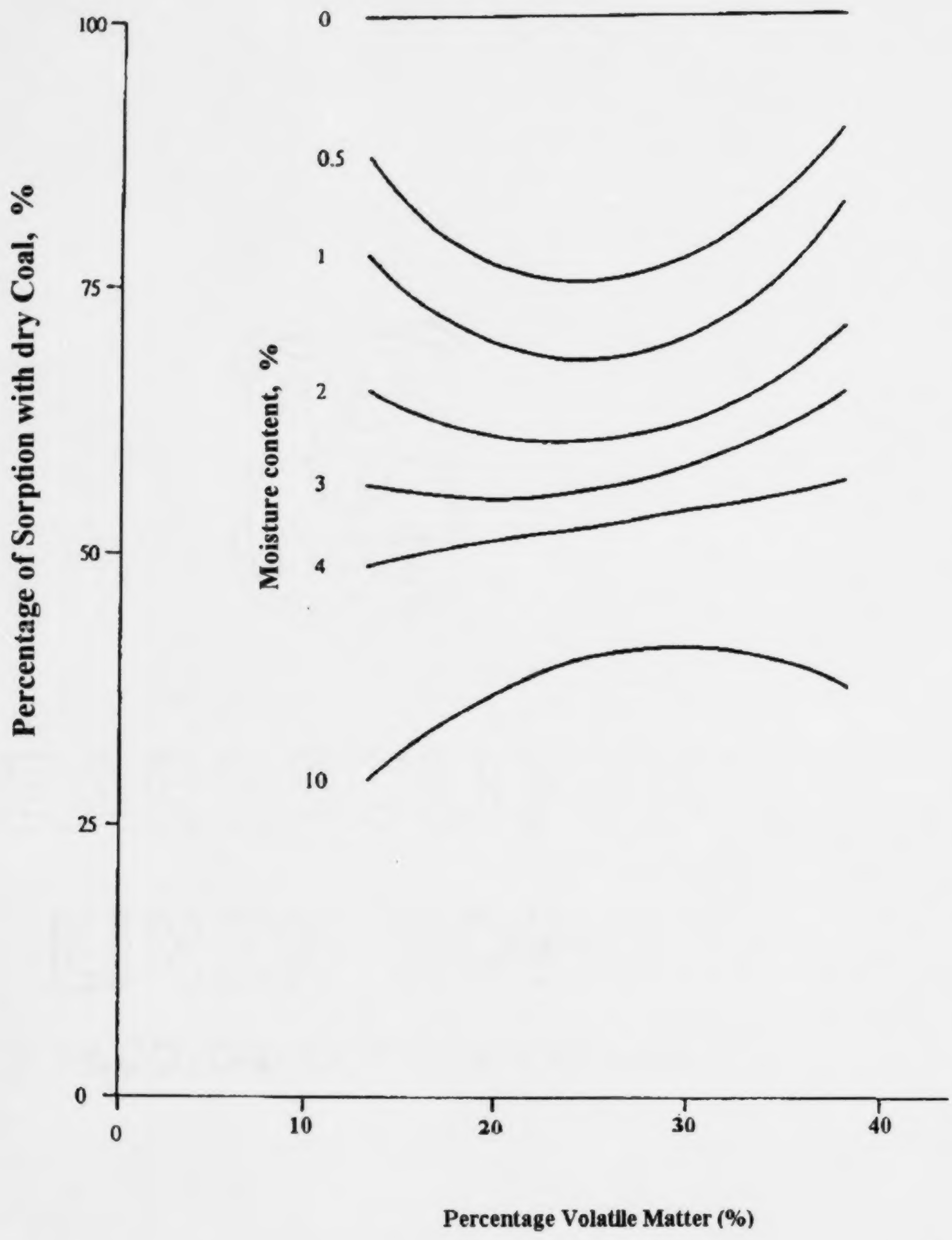


Fig. 2 - 7 The Effect of Moisture Content on Sorption Capacity of Coals of Various Volatile Contents (after Khodot)

It has been found that at a critical value of γ ($\approx 5\%$), saturation occurs and no further drop in gas adsorption rate occurs. This may be due to the fact that the value of the moisture content is related to the oxygen content of the coal and begins to play a key role in the adsorption capacity of the coal above the critical value of about 5%. The critical moisture content may be calculated from the following equation [12]:

$$\gamma = \frac{(0.05\, X_o - 0.083)}{0.25\,(1 - 0.5\, X_o - 0.083)} \qquad (2 - 4)$$

where X_o = oxygen content of the coal, %

Absorption of methane by coal is not widely considered in the literature to play any significant role in the flow of methane from coal during mining operations as it is very small compared to that in the adsorbed state and can only be liberated into the mine workings from heating or chemical treatment.

A larger proportion (up to 95%) of the methane in coal seams is considered to be in the adsorbed state on the internal surface of the coal in a monomolecular layer [12, 13]. The high gas adsorption rate of methane is due to the very large internal surface area of coal (estimated to range between 20 and 200 m^2/g) [2, 3].

The amount of gas contained in coal seams is related to a number of factors which include [3, 12]:

1) the porosity of the rock.
2) the permeability of the rock.
3) the local geologic features in the area (presence or absence of cleats, faults, folding, dip, etc.).
4) the nature of the strata.
5) the depth below surface.
6) the moisture content of the coal or strata.
7) the ambient temperature.

The methane gas that is encountered during the mining process is partly made up of desorbed gas and the free gas contained in the pores and fissures of the coal and surrounding strata. The process of desorption may be expressed by the equation [4, 14]:

$$r(t) = \frac{q(t)}{Q(\infty)} \approx \sqrt{\left\{1 - \exp\left(\frac{-4\pi^2 Dt}{d^2}\right)\right\}} \qquad (2 - 5)$$

where $Q(\infty)$ = Quantity of gas (m^3) which can be liberated between pressure P_1 and the atmospheric pressure P_b ($P_b < P_1$), after an infinite time P_1 being the prevailing pressure of gas at the particular depth.

$r(t)$ = the degree of desorption after time t

$q(t)$ = Quantity of gas (m^3) which can be liberated between pressure P_1 and atmospheric pressure P_b, after time (t) when pressure changes quickly from P_1 to P_b

t = time in seconds

D = diffusion coefficient, cm^2/s

d = Equivalent particle diameter (cm) = $\frac{6V}{A_o}$

where V = particle volume, m^3

A_o = Surface area, m^2

For methane gas, $D \approx 10^{-10}$ cm^2/s

When t is small (i. e. $t < \frac{d^2}{\pi D}$), equation (2 - 5) simplifies to:

$$r = \frac{q(t)}{Q(\infty)} \approx \frac{12}{d}\sqrt{\frac{Dt}{\pi}} - \frac{12Dt}{d^2} \qquad (2 - 6)$$

where r = degree of methane desorption.

At start of desorption while r(t) in equation (2 - 5) remains below 25% and since D and d are both constants for a given sample, equation (2 - 6) simplifies to:

$$\frac{q(t)}{Q(\infty)} = k_1 \sqrt{t} \qquad (2 - 7)$$

because Dt is much smaller than $\sqrt{Dt}$ (D <1 and t is small) where $k_1 = \frac{2\,A_o}{V}\sqrt{\frac{D}{\pi}} = \frac{12}{d}\sqrt{\frac{D}{\pi}}$

Thus for very short periods of time, the rate of desorption is proportional to the square root of the time. Equation (2 - 7) is widely used in Europe while in the United Kingdom, desorption rates are calculated using the empirical relation [7]:

$$r(t) = \frac{q(t)}{Q(\infty)} = 1 - \exp\left[-\left(\frac{t}{t_0}\right)^n\right] \qquad (2 - 8)$$

t_o = time for desorption of 63% of gas (in seconds)

n = $\frac{1}{3}$ for bituminous coal while $n = \frac{1}{2}$ for anthracites.

From equation (2 - 8), at start of desorption when r(t) is less than 25% and for any particle shape:

$$r(t) = \frac{q(t)}{Q(t)} = k_2\, t^n \qquad (2 - 9)$$

where k_2 is a constant which can be determined experimentally.

From equation (2 - 9), desorption initially follows a law in $\sqrt[3]{t}$ for bituminous coal and $\sqrt{t}$ for anthracites [7].

In brief, the foregoing equations show that the amount of methane gas contained in coal seams (*in both the free and adsorbed states*) is directly proportional to the porosity of the rock and to the absolute pressure of the gas but inversely proportional to the atmospheric pressure, the absolute temperature and to the moisture content of the coal.

2.3.3 Estimation of Gas Content of Coal Seams

There are two general approaches that have been adopted in the determination of gas emission into development headings [4] - direct and indirect methods.

.1 Direct Methods

In the direct methods of gas content estimations, coal samples are taken from the seam by coring and transferred quickly to a sealed vessel (bomb) to minimize the initial gas loss. After measurement in the laboratory of the quantity of gas released into the vessel during transit, the remaining gas is released for measurement by pulverizing the sample in a sealed mill.

The total gas content (Q_t) of the core is obtained from the following equation [4]:

$$Q_t = Q_1 + Q_2 + Q_3 \qquad (2 - 10)$$

where Q_1 = gas lost between drilling of the core and transfer of the core from the borehole to the sealed vessel (bomb).

Q_2 = gas liberated from core after placing it in the bomb.

Q_3 = residual gas (i.e. gas liberated when the coal sample is crushed).

Corrections are made for gas content loss prior to sealing the sample; for the quantity remaining sorbed by the coal at the final equilibrium in the mill (using the isotherm relationship) and for the ash content of the coal sample in the calculations of the total gas content [15].

.2 Indirect Methods

In the indirect methods of estimation of gas content, the methane is measured in the seam and the gas content found from the relationship between the pressure and gas content, the "isotherm" being established from laboratory experiments [15]. This process requires a near-perfect seal in an in-seam borehole the pressure measurement of which is subject to problems of gas leakage and strata water pressure. The technique applied consists of subjecting the sample to gas pressures and measuring the gas uptake of the sample at a given pressure until equilibrium is established. The amount of gas adsorbed is then calculated. The pressure is then varied and the volume of gas adsorbed until equilibrium is reached is then recalculated. By varying the pressure, a complete gas adsorption curve is obtained. The amount of adsorbed gas can be calculated using either volumetric or gravimetric methods. The laboratory measurements usually require that the coal sample be at the same temperature and moisture content as the seam, which is extremely difficult to obtain.

Table 2 - 3 gives the gas contents of Canadian coals [16]. Depending on the rank of the coal and depth, Alberta coals contain 5 to 20 m^3/tonne of methane. Using the direct and indirect methods of gas estimation [2], the U. S. Bureau of Mines determined gas content of various seams as shown in Table 2 - 4. Table 2 - 5 shows the gas contents of some U. S., U. K., Australian and South African seams [17, 18].

Table 2 - 3 Gas Content of Various Canadian Coals

Location	Gas Content (m^3/tonne)	Remarks
Alberta Mountains	15	At shallow depths (< 100 m)
Alberta Mountains	20	At moderate depths (up to 500 m)
Alberta Foothills and Plains	0 - 10	
Nova Scotia	6 - 10	
Vancouver Island	1 - 12	

Source: Proudlock (1990)

2.3.4 Methane Emission

Figs. 2 - 8 and 2 - 9 show the desorption processes and mode of gas flow and transport of methane gas in a coal seam. The free gas first diffuses from the desorption site through the micropore structure of the coal and then flows along the fissures and fractures in the coal bed [8]. The flow of the methane gas along the fissures and fractures within the coal is caused by the difference between the in-situ gas pressure and the pressure of the mine air [2].

Table 2 - 4 **Comparison of Direct and Indirect Methane Contents for Selected Coalbeds in the U. S.**

Location	Coalbed	Direct Method m^3/tonne (STP)	Indirect Method m^3/tonne (STP)
Vesta No. 5	Pittsburgh	2.6	3.4
Loveridge	Pittsburgh	5.8	5.2
Howe	Hartshorne	11.1	10.5
Beatrice	Pacohontas No. 3	12.1	13.5
Inland	Illinois No. 6	1.7	2.7
Inland	Illinois No. 5	0.9	0.5
Kepler	Pocahontas No. 3	7.9	7.8
Price	Castlegate (subseam No. 3)	4.2	6.2, 5.0

Source: Curl (1978)

Table 2 - 5 **Gas Contents of Various U. S., U. K., Australian and South African Coal Seams**

Source	Seam	Gas Content (m^3/tonne)
	United States of America	
Illinois	Illinois Seam	9.70
Pittsburgh, PA	Pittsburgh Seam	5.30
Virginia	Pacohontas Seam	8.00
	United Kingdom	
Ramscroft Colliery	Waterloo Seam	9.30
Cynheindre Colliery	Big Vein Seam	18.1
	Republic of South Africa	
Tshikondeni	R. O. M.	6.00
Hlobane	Gus	5.20
Hlobane	Dundas	5.10
Ermelo	C Seam Lower	5.10
Umgala	Gus	4.40
Greenside)	5 Seam	3.00
Matla	4 Seam	1.70
	Australia	
Bulli Seam		7 - 10
Balgownie Seam		9.6

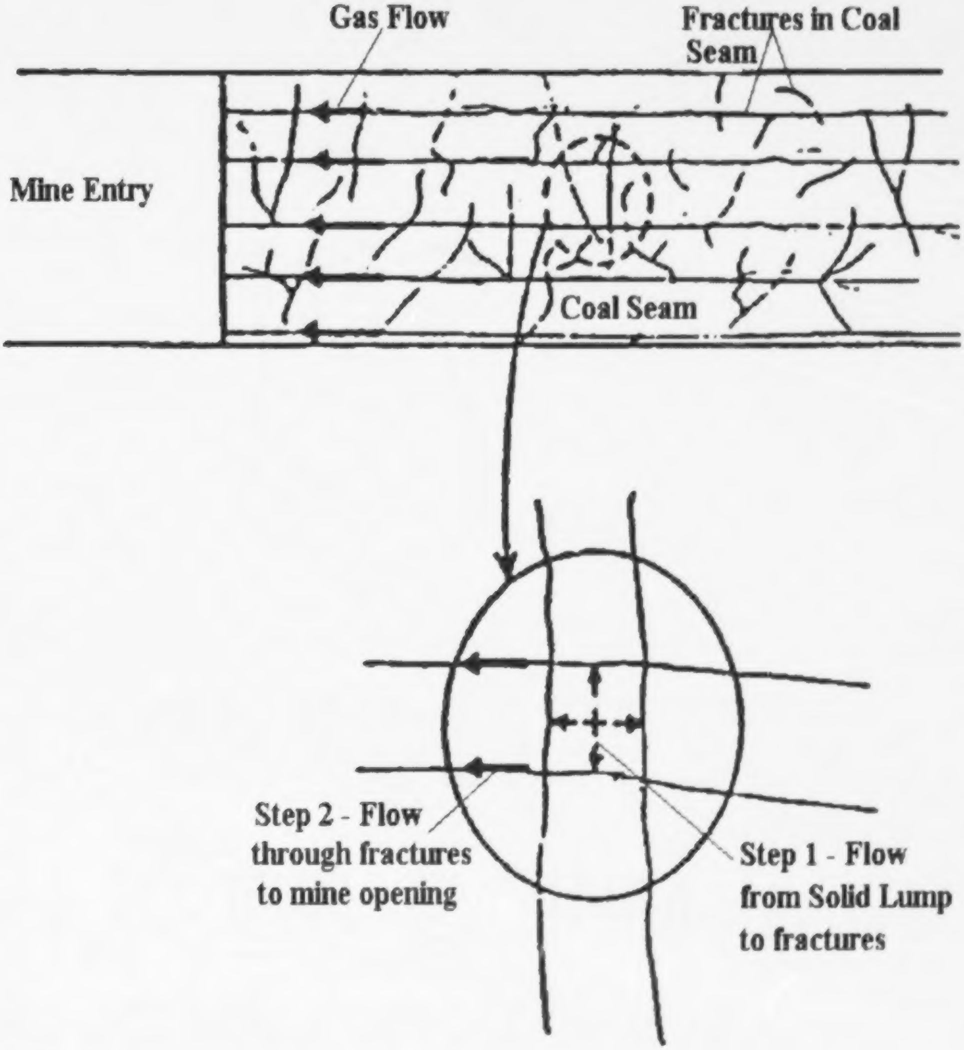

Gas Flow
Fractures in Coal Seam
Mine Entry
Coal Seam
Step 2 - Flow through fractures to mine opening
Step 1 - Flow from Solid Lump to fractures

Fig. 2 - 8 Modes of Gas Flow through Coal

Source: Gunther (1965)

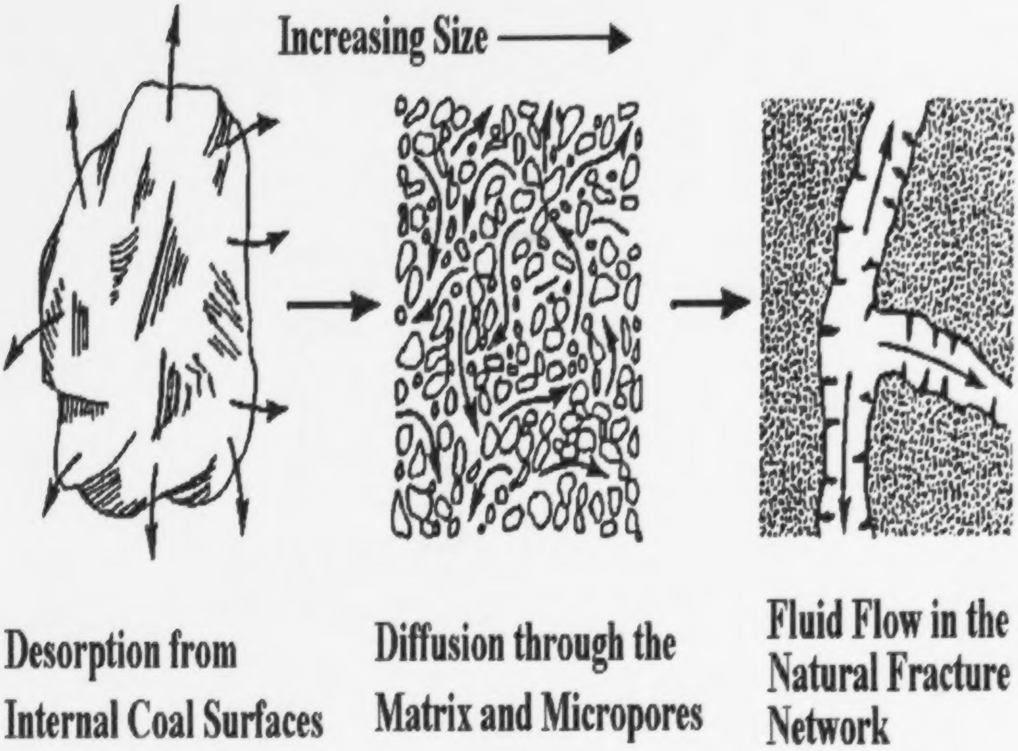

Increasing Size
Desorption from Internal Coal Surfaces
Diffusion through the Matrix and Micropores
Fluid Flow in the Natural Fracture Network

Fig. 2 - 9 **Processes in the Transport of Methane Gas in a Coal Seam**

Among the factors that determine the rate at which methane gas is emitted into the mine openings are [2, 4]:

1. the gas content of the coal.
2. the permeability of the coal.
3. the depth of workings.
4. the local geologic conditions (presence or absence of joints, faults, cleats, etc.).
5. the thickness of the seam being worked.
6. the method and rate of mining.
7. the type of strata above and below the coal seam.
8. the effect of variations in barometric pressure.
9. the type or method of ventilation.

Fig. 2 - 10 shows the gas content as a function of depth for the Mary Lee Seam in the U. S. The permeability of a coal seam has been found to depend strongly on the type of coal and on the amount of water in the seam. Unfractured solid coal has low permeability which limits the flow of gas into mine openings. Most bituminous coals are highly fractured and therefore have high permeabilities [2, 13].

It has been found that the thicker the seam the higher the gas content per unit surface area exposed and the wider the area of ground that is disturbed when the seam is mined out. Similarly, mining methods that result in a lot of ground subsidence and/or cause substantial amount of fracturing of the surrounding strata (e. g. caving methods) give rise to higher gas emissions into the mine workings. This is because they create a larger zone of disturbance around the mine excavations which allow gas to enter the openings not only from the coal seams being worked but also from the overlying and underlying strata.

Furthermore, the greater the rate of advance of the face, the less is the time available for coal in-situ to desorb the methane it contains and the greater the remnant gas in the coal when it is cut [12]. For a given face in the United Kingdom, the relationship between the rate of gas emission and face advance is of the form [19]:

$$E = k\,R^{0.8} \qquad (2 - 11)$$

where E = Gas emission rate (m^3/s)

k = a constant

R = rate of advance of face (m/s)

Fig. 2 - 11 shows the degree of gas emission relative to the rate of advance of the face in a typical bituminous coal face. It is estimated that almost half of the gas contained in coal is emitted at the face and a quarter while it is being transported out of the mine on conveyors and other mine transport systems while the remainder remains in the coal when it leaves the mine [3].

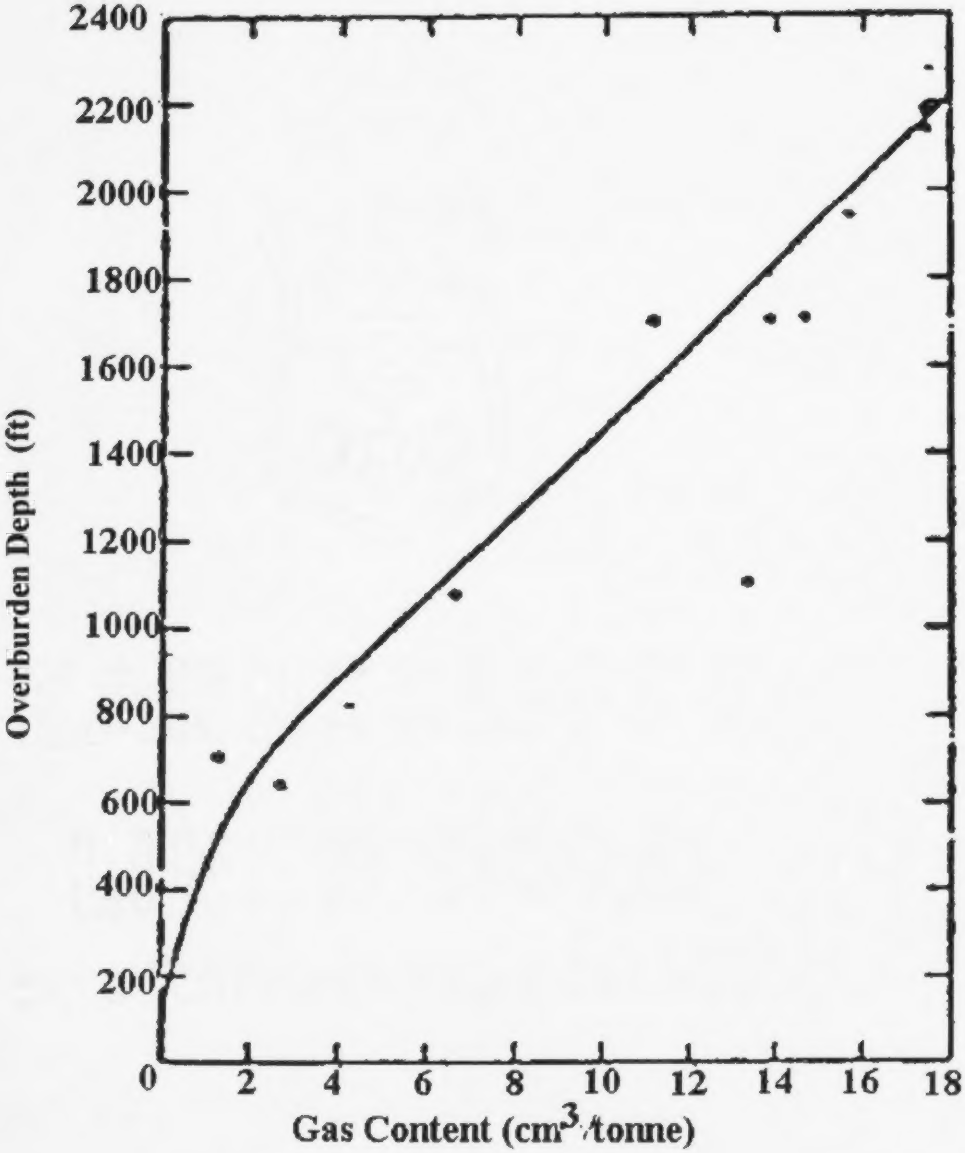


Fig. 2 - 10 Relationship between Gas Content and Depth in the Mary Lee Seam

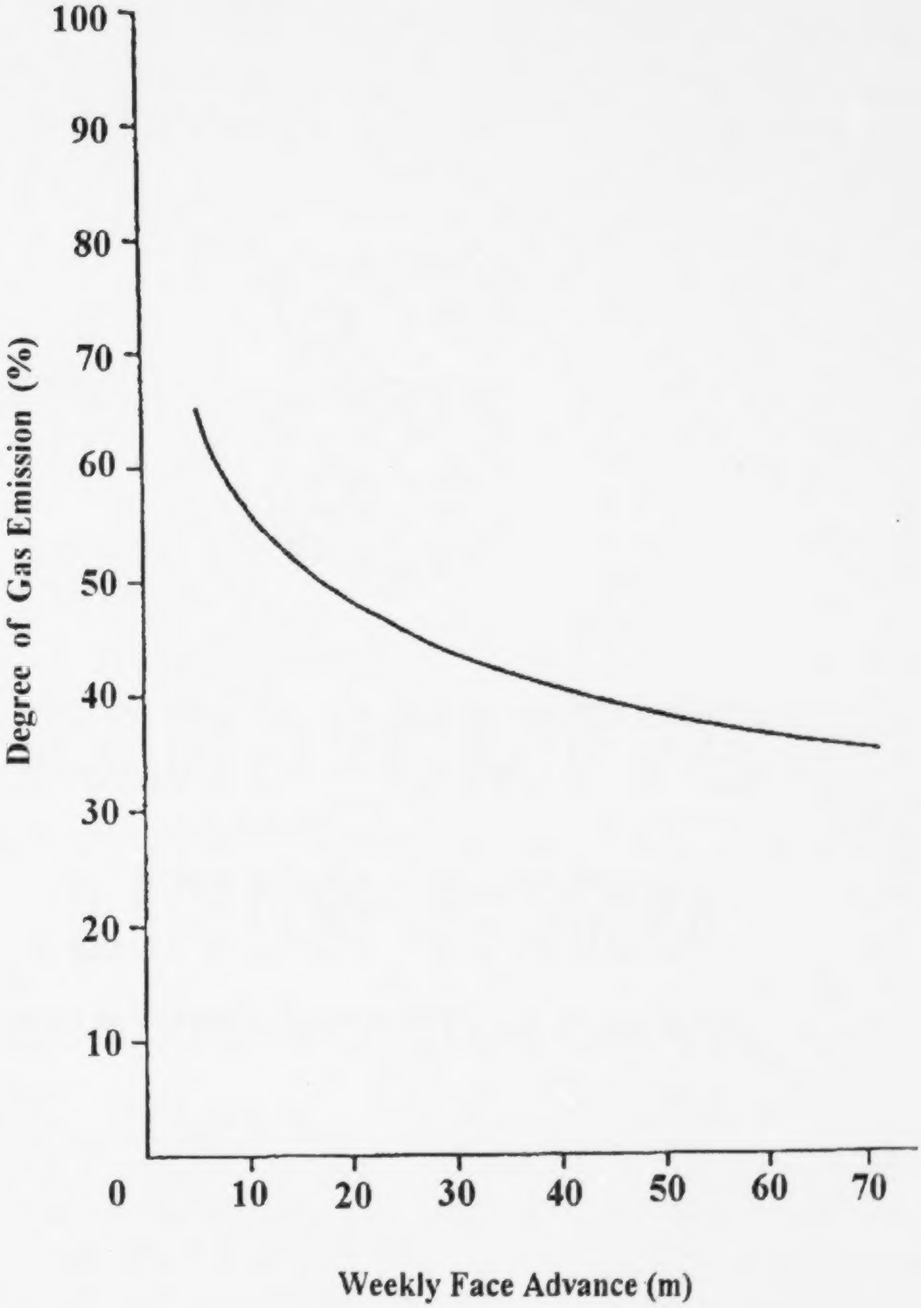


Fig. 2 - 11 The MRDE Curve for the Degree of Gas Emission from a Worked Seam [Source: Dunmore (1980)]

Equation (2 - 12) gives the relationship between the gas emission rate and the rate of production of coal [12]:

$$E = \alpha\sqrt{P} + \beta \qquad (2 - 12)$$

where E = methane gas emission rate (m^3/s)

α and β are constants

P = production rate (tonnes/day)

Fig. 2 - 12 depicts the relationship between gas emission rate and the weekly coal output in two U. K. longwall faces [2] while Fig. 2 - 13 shows the zones of relaxation around a mine opening from which strata gases often emanate. These zones are:

1. Zone One which comprises the zones nearest to the excavation or mine opening (labeled Z1 and Z'1 in Fig. 2 - 13). The beds in this zone fracture into blocks and are displaced relative to each other. The fissures formed and voids created in Zone One do not close completely when recompressed (when the strata takes up load). Thus this zone remains a very permeable region around the working. Zone Z'1 is very small compared to Z1(and can not be shown on Fig. 2 - 13). Consequently, much of the methane emission emanates from the roof in this zone. In areas where caving methods are employed, the thickness of Zone One is about 3 to 8 times the height of the excavation (face) depending on the strength of the fractured beds. In times of falling barometric pressure or changes of ventilation, the voids in Zone One (which act as a reservoir of methane) release the stored methane into the mine openings leading to an increase in the concentration of methane in the general body of the air and this could lead to layering of the gas if the air velocities in such openings are low [7].
2. Zone Two (labeled Z2 and Z'2 in Fig. 2 -13), which is much larger, completely envelopes Zone One. The rocks in this zone fracture and the beds separate from each other. However, when the rocks in this zone are recompressed, the natural microfissures are partially closed resulting in a

reduction in the permeability of the rock zone. Zone Z'2 may be up to 50 m below the face while Z2, depending on the size of the working and method of mining, could be over 100 m [7].

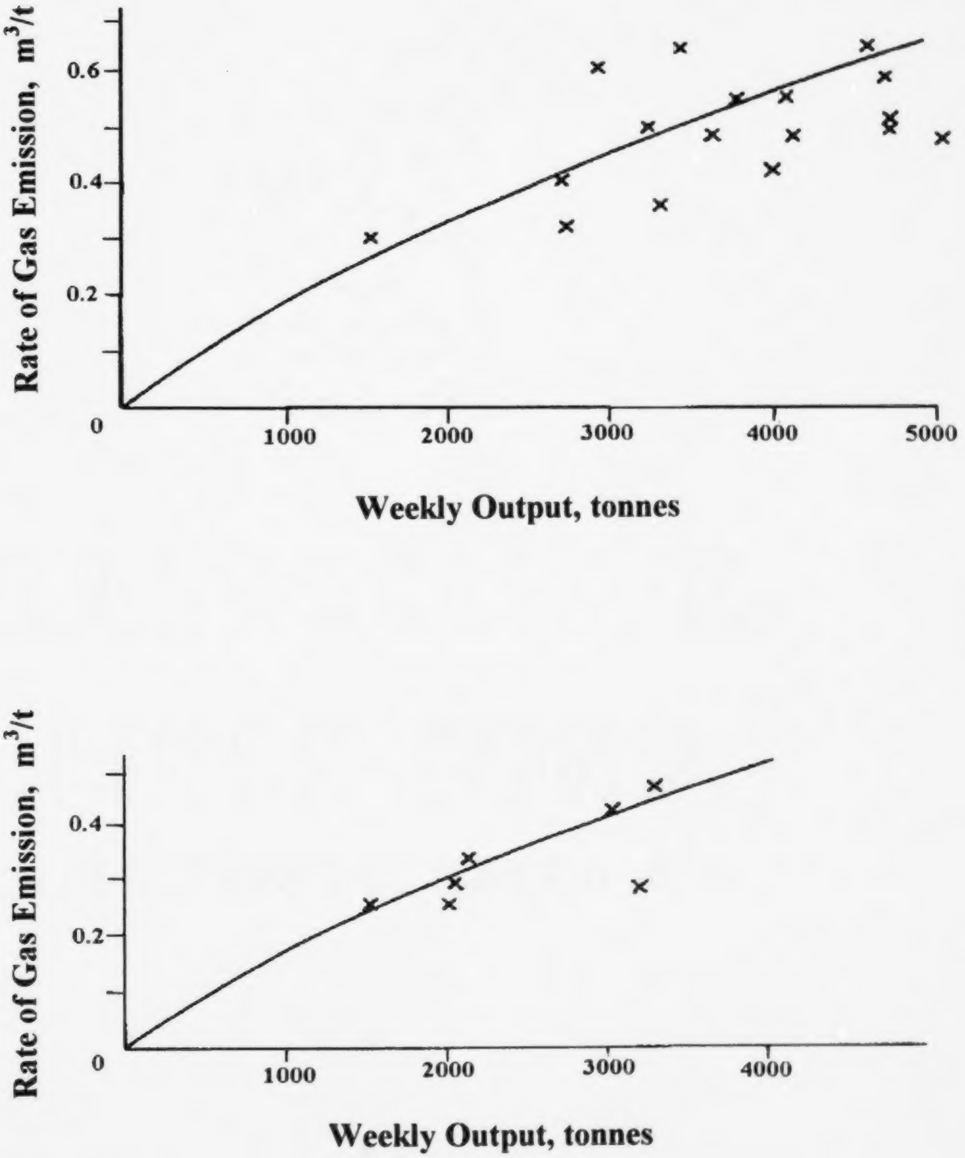


Fig. 2 - 12 Gas Emission from Two UK Longwall Faces

Source: Curl (1978)

3. Zone three (Z3 and Z'3). This is the zone below Z'2 in the floor and above Z2 in the roof (i.e. when the face of the excavation is in virgin ground). The ground in this zone is also relaxed but the rocks are hardly fissured [7]. The degree of relaxation of the ground in this zone is however sufficient for coal seams to become permeable and for gas to escape into nearby mine openings, etc.

At a height of 200 m and a depth of 100 m from a worked seam the emission rate is considered negligible.

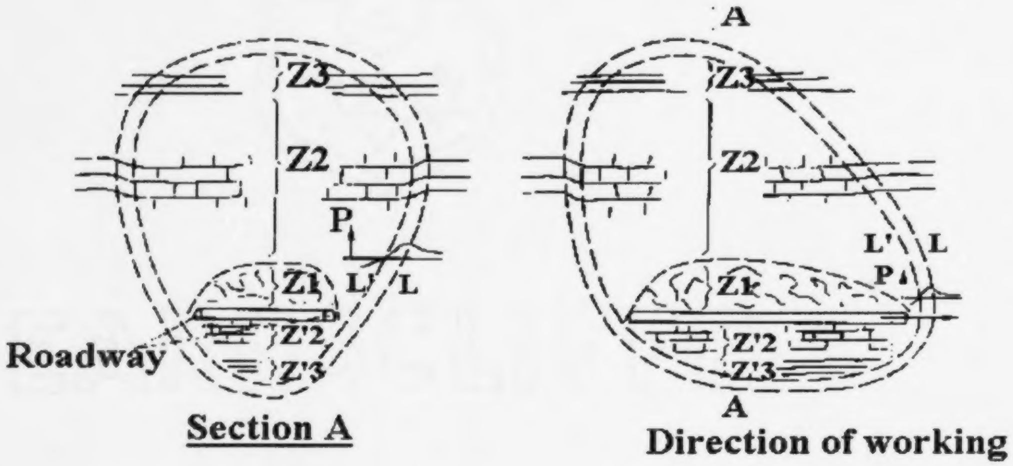


Fig. 2 - 13 Relaxed Zones Around a Working

Rapid drops in pressure over short periods (i. e. 0.4 to 0.8 kPa drop in 3 hr.) lead to an increase in the rate of emission of methane gas from coal seams [20]. Falling barometric pressure increases the gas flow due to the expansion of methane held in the pore spaces of the coal. Conversely, a rising barometer will decrease the flow by compressing the gas in the pores. However, the effect depends upon the rate of change of the barometric pressure and the percentage of open voids in the coal [9]. A forcing ventilation system, like a rising barometric pressure, suppresses the emission of methane from the strata while an exhausting system tends to enhance the methane emission rate.

The effects of barometric pressure on methane emission rate may occur when either the atmospheric pressure falls rapidly over a long time or the ventilation system (when forcing) is stopped for some time due to power failure.

2.3.5 Estimation of Methane Emission Rates into Development Headings

There are two basic approaches adopted in the estimation of gas emission into development openings [4]. These are:

1. theoretical methods and
2. empirical methods

In the theoretical methods, the rate of gas emission into the excavations is calculated assuming that the laws of flow of gas through a porous medium are applicable. These estimations require field permeabilities of the coal seam and of the surrounding strata, gas pressures and gas content estimations. It is often assumed in these calculations that gas filtration laws (such as those of diffusion and Darcy's flow) are applicable to the flow of gas into the mine openings, that the gas is an ideal gas and its flow is isothermal, the flow direction is linear and unidirectional and that the adjacent coal strata is relatively impervious [18]. The empirical methods, on the other hand, are based upon on-site measurements in mines.

A number of organizations in Europe, Russia and North America have developed methods and techniques which enable the flow of methane into mine workings in coal mines to be predicted. The notable methane prediction techniques developed are [2, 7]:

1) Gunther's method later called the Jeger method (developed in France).
2) Schultz's method (Germany).
3) Winter's method (Germany).
4) Flügge's method (Germany).
5) Koppe's method (Germany).
6) Lidin's method (Russia).
7) Airey's method (United Kingdom).
8) the Institut National des Industries Extractives (INIEX) method (Belgium)

9) the Barbara Experimental Mine method (Poland)

Notwithstanding the inherent differences in approach, all these methods consider the same basic parameters [2]:

a) the nature of the strata above and below the worked seam.

b) the desorbable gas content of the seam being worked, and where possible, of the adjacent seams and strata.

c) the zone of gas emission in both the roof and the floor.

d) the degree of gas emission from adjacent seams and strata.

The literature is replete with the details of these methods [2, 4, 7]. Basically, the rate of emission of methane gas from the seam in all the methods is considered to be directly proportional to the thickness of the seam, to the rate of advance of the heading and to the methane content of the seam. The use of the foregoing methods in estimation of the methane emission rates in a roadway depends primarily on the preference of the individual researcher and on the local geologic and mine operational conditions.

Typical average methane emission rates of the top 25 coal mines in the U. S. in 1987 are given in Table 2 - 6 [17]. For comparison, the average methane emission rates measured in civil engineering tunnels driven through coal measure strata spread throughout five states in the U. S. ranged between 0.00236 and 0.0236 m^3/s while the peak emission rates were as high as 0.1746 m^3/s in one case [21].

2.3.6 Methane Diffusion and Layering

The rate of Diffusion of a Gas is related to its density in relation to air (Graham's Law). The relationship is given by the equation:

$$\text{Rate of diffusion} \propto \sqrt{\frac{\rho}{\rho_g}} \propto \sqrt{\frac{1}{s_g}} \qquad (2-13)$$

where ρ = density of air

ρ_g = density of gas

s_g = specific gravity of the gas

Table 2 - 6 Average Methane Emission Rates of the Top Twenty-Five Coal Mines in the U. S. in 1985.

No.	Company Name	Mine Name	Methane 10^6 cfd	Methane 10^3 m^3/d	State	Coalbed	Methane m^3/s
1	Jim Walter Resources Inc	Blue Creek #7 Mine	17.2	486.76	AL	Mary Lee	5.63
2	Jim Walter Resources Inc	Blue Creek #3 Mine	16.6	469.78	AL	Mary Lee	5.44
3	Jim Walter Resources Inc	Oak Grove Mine	16.1	455.63	AL	Mary Lee	5.27
4	Jim Walter Resources Inc	Blue Creek #4 Mine	14.6	413.18	AL	Mary Lee	4.78
5	Jim Walter Resources Inc	Blue Creek #5 Mine	11.1	314.13	AL	Mary Lee	3.64
6	Consolidation Coal Co.	Loveridge # 22 Mine	10.7	302.81	WV	Pittsburgh	3.50
7	Eastern Associated Coal	Federal #2 Mine	9.2	260.36	WV	Pittsburgh	3.01
8	Consolidation Coal Co.	Humprey #7 Mine	7.3	206.59	WV	Pittsburgh	2.39
9	VP 5 Mining Co	VP No. 5 Mine	7.2	203.76	VA	Pacohontas # 3	2.36
10	U. S. Steel Mining Co Inc.	Cumberland Mine	6.9	195.27	PA	Pittsburgh	2.26
11	Beatrice Pocahontas Co	Beatrice Mine	6.8	192.44	VA	Pacohontas # 3	2.23
12	Garden Creek Pocahonta	Virginia Pocahontas #6	6.6	186.78	VA	Pacohontas # 3	2.16
13	Island Creek Coal Co	Virginia Pocahontas #3	6.4	181.12	VA	Pacohontas # 3	2.10
14	Consolidation Coal Co.	Buchanan No. 1 mine	6.0	169.80	VA	Pacohontas # 3	1.97
15	Island Creek Coal Co	Virginia Pocahontas #1	5.5	155.65	VA	Pacohontas # 3	1.80
16	Clinchfield Coal Co	Mcclure # 1 Mine	5.0	141.50	VA	Jawbone	1.64
17	Consolidation Coal Co.	Blacksville #2 Mine	4.9	138.67	WV	Pittsburgh	1.60
18	Emirald Mines Co	Emerald Mine	1.8	135.84	PA	Pittsburgh	1.57
19	Mid-Continent Resources	Dutch Creek #1 Mine	4.3	121.69	CO	Coal Basin B	1.41
20	Consolidation Coal Co.	Osage #3 Mine	4.2	118.86	WV	Pittsburgh	1.38
21	Consolidation Coal Co.	Arkwright #1 Mine	3.9	110.37	WV	Pittsburgh	1.28
22	Beckley Coal Mining Co	Beckley Mine	3.7	104.71	WV	Beckley	1.21
23	Beckley Lick Coal Co	Bonny Mine	3.4	96.22	WV	Beckley	1.11
24	Consolidation Coal Co.	Robinson Run #95 Mine	3.4	96.22	WV	Pittsburgh	1.11
25	U. S. Steel Mining Co	Somerset Mine	3.3	93.39	CO	B, C	1.08

Source: Grau III (1987)

From equation (2 -13) a lighter gas than air will diffuse faster than one heavier than air. The smaller the specific gravity, the more rapid the rate of diffusion. It has been observed that diffusion is aided by turbulence and temperature [1, 4].

Layering of methane occurs in coal mine openings where the ventilation airstream generates insufficient turbulence. In such cases any methane gas present will stratify and form a persistent layer which moves along the roof. Among the factors that affect the formation of methane layers are the degree of turbulence, the rate of methane emission from the strata, the dip or inclination of the airway and the roughness of the airway. Fig. 2 - 14 shows the variation of the length of the methane layer with respect to the layering number (N_l) for a level airway while Fig. 2 - 15 depicts methane layering in roadways of different inclinations [22].

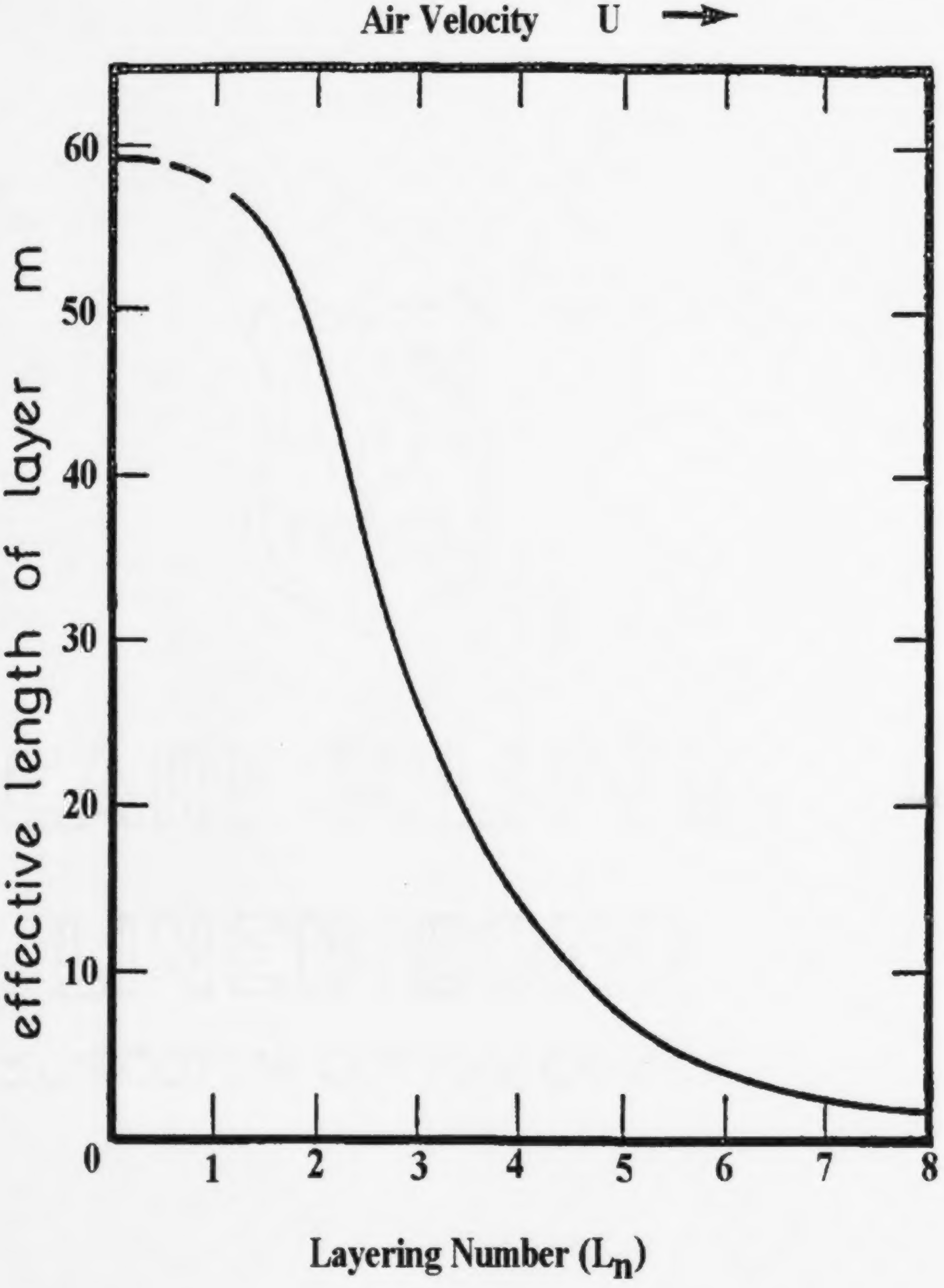
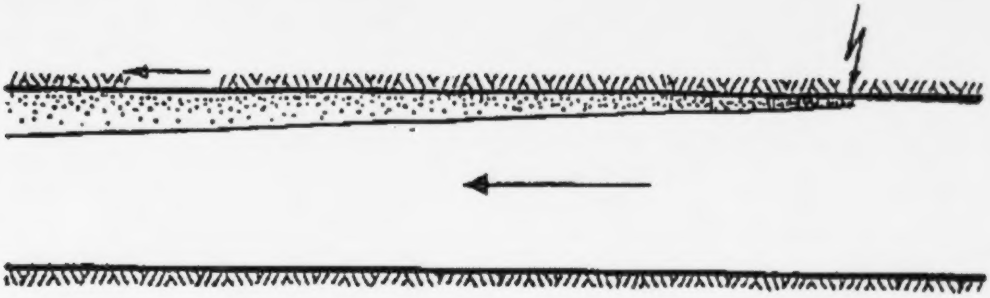
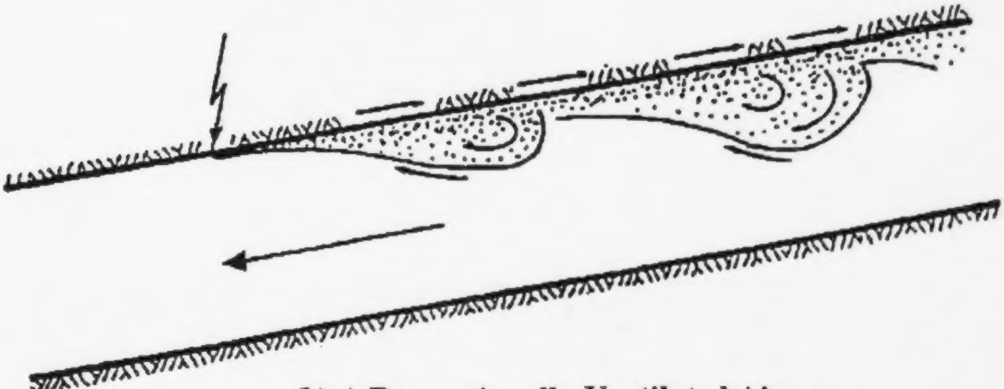


Fig. 2 - 14 Variation of Layering Number for Level Airways



(a) A Level or Ascentionally Ventilated Airway



(b) A Descentionally Ventilated Airway

Fig. 2 - 15 Methane Layering in Roadways of Different Inclinations

The Layering Number (N_l), which indicates the likely occurrence of methane layering, is given by the following equation:

$$N_l = \frac{V_u}{1.8}\left(\frac{b}{Q_{CH_4}}\right)^{\frac{1}{3}} \qquad (2 - 14)$$

where V_u = air velocity in upper half of airway, m/s

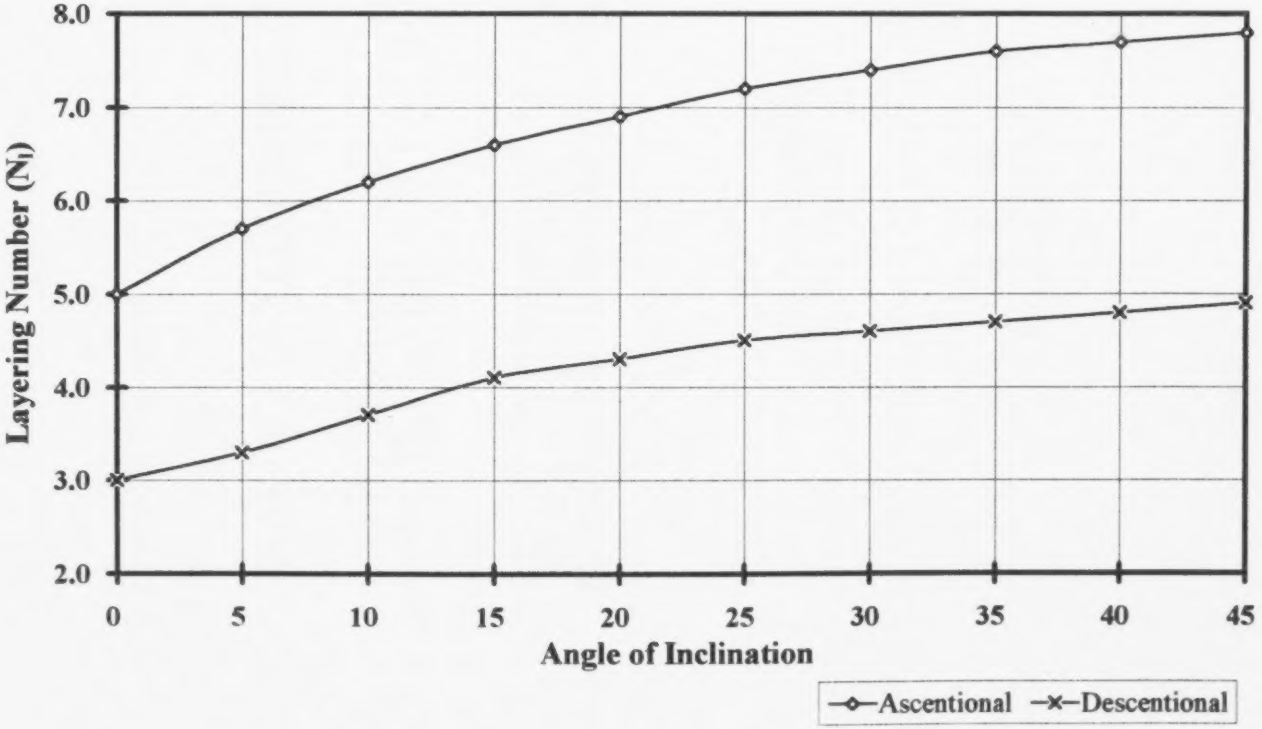
Q_{CH_4} = methane inflow rate, m^3/s

b = airway width, m

Fig 2 - 16 is a graph of the recommended minimum Layering numbers as a function of the roadway inclination [23].

Tests show that irrespective of airway slope when $N_l > 5$, methane layering is not likely to occur [1, 4, 9]. In development headings, a tendency to methane layering indicates the need to improve the auxiliary ventilation system [9]. In typical coal mine openings (with moderate gas inflow), high air velocities (≥ 1 m/s) are required to cause turbulence in the airflow and to prevent layering of methane gas.

Fig. 2 - 16 Relationship between Minimum Layering Number and Roadway Inclination



Chapter Three

MINE VENTILATION SYSTEMS

3.1 INTRODUCTION

Mine ventilation systems are generally grouped into main, booster and auxiliary ventilation systems. Every ventilation system has a pressure source (fan), connecting ducts (mine openings, ventilation ductings, etc.) and control devices (stoppings, doors, regulators, airlocks, etc.) as essential components [1]. Some amount of natural ventilation may co-exist alongside the fans. The main function of the ventilation system is quantity and quality control which involves the control of the movement, direction and magnitude of air through mine openings and the dilution of toxic and explosive contaminants to safe levels. Effective air distribution is required to create the desired working climate underground.

Ventilation systems in metal and non-metal mines generally differ in the characteristics of the mining system and in the characteristics of the major atmospheric contaminants generated during mining. These factors are taken into consideration when designing ventilation systems so as to supply fresh air in sufficient quantities to dilute and safely remove the contaminants from the workings [1].

The main contaminants found in underground coal mines are methane gas and dust. Except in very dusty and radioactive mines or where diesel powered equipment are in use, generally when the operating ventilation system meets the requirements of safely diluting and removing methane from the workings, then all other ventilation requirements are met. Due to the explosive nature of methane, ventilation requirements in coal mines are more rigid than those in metal mines and are normally stipulated by Federal, State or Provincial laws. Coal seams are generally flat-lying, of large aerial extent and of moderate depths. As a result they often have longer mine openings through which air has to pass (resulting in significant pressure losses) before getting to working places. Consequently, coal mines require main fans with high static pressures to withstand the high pressure losses inherent in long airways.

3.2 MAIN VENTILATION SYSTEMS

The main ventilation system in a mine comprises the entire setup of main fans, mine openings, ventilation ductings and air control system devices that are employed to take fresh air from the surface, supply it to workings and to remove contaminants from the mine workings to the surface. In coal mining, main ventilation systems often have one or more main fans (exhausting or forcing) located on the surface and connected in parallel. Depending on the rates of methane emissions and the type of mining method employed in the mine, very large quantities of fresh air {over 1000 m^3/s (2×10^6 cfm) in some cases} are often required to be supplied by the main ventilation system. As the air velocities would be very high if single entries were used *(> 4 m/s which would lead to the air picking up settled dust in the roadways and creating a health hazard),* most coal mines have multiple intake and return entries in their main ventilation system.

3.3 BOOSTER VENTILATION SYSTEMS

Booster ventilation is actually a form of auxiliary ventilation where the pressure loss through a high resistance split in a parallel circuit that the main fan must overcome is reduced by the introduction of a booster fan in the affected split. Booster fans are usually installed in the return airways to increase the total pressure head in the mine ventilation circuit and to increase the total effective air at the furthest point away from the surface fan and portals. When appropriately sited, a booster fan will increase the pressure gradient between intake and return airways for a short distance on the intake side of the fan thereby increasing possible leakages but will decrease the gradient on the discharge side for a longer distance thereby decreasing leakages. The net result is a more effective use of an increased mine air flow by the combined effects of a larger total pressure head and lower leakage quantities. Booster fans are not treated in this work.

3.4 AUXILIARY VENTILATION SYSTEMS

As most of the gas emitted is usually at the face where new coal and rock is worked and new face is being exposed, there is a need for the ventilation system to supply adequate amounts of intake air to the face to maintain the ambient air quality within the standards of good occupational health and safety practices. However due to increasing depths of mining and the greater distances of working faces from the shafts, the use of new mining methods and equipment which allow faster advances in working areas resulting in the liberation of large amounts of gases, dust and heat, the promulgation of more stringent health and safety laws for workers working in the face, the main ventilation air stream is often insufficient, ineffective or unavailable at distant workings and faces. Under such circumstances it is necessary to supplement the main ventilation system in order to create adequate working conditions at such places. The practice of augmenting the main ventilation system is termed auxiliary ventilation [1].

In coal mines, auxiliary ventilation systems are required to be employed as soon as the heading or working place is advanced beyond the last open cross-cut. The safety and efficiency of any underground operation depends, to a large extent, on the auxiliary ventilation system [19]. Ventilation of development ends (*the main area of this work*) is the most frequent and important application of auxiliary ventilation. Depending on the length of the heading, the auxiliary ventilation system is usually the primary means of assuring that the air quantity and quality requirements are met at the face.

The following factors are considered in the selection of an appropriate auxiliary ventilation system for a working place:

1) amount of air that will be required taking into consideration the number of men required to work there, the rate of advance of the face, the type of mining operations (whether blasting or cutting of the ore or coal is to be done); the type and capacity of the mining equipment (i. e. whether diesel powered equipment will be employed) and the gas emission rates.
2) the size and type of fan required.
3) the size and type of duct.

The determination of the quantity of air for any given mining area is governed mainly by Federal, State or Provincial laws which often state the minimum requirements.

Auxiliary ventilation systems in coal mines serve a number of purposes the most significant of which are [1, 20] to provide conditioned and uncontaminated air in sufficient quantities and qualities to working places; to remove firedamp and other noxious and explosive gases from the workings and to remove particulate contaminants such as dust.

Depending on the components employed, there are two broad types of auxiliary ventilation systems employed to ventilate development headings:

1. Static systems whose components have no moving parts. These include line brattice and other systems which make use of the prevailing pressure head of the main ventilation system to supply air to the faces [1, 24, 25].
2. Dynamic systems which have components with moving parts. These include:
    a) Primary forcing (blowing) system.
    b) Primary exhausting system.
    c) Overlap systems.

In all dynamic systems the fans are interlocked with the heading machine such that power to the heading machine is automatically cut off when the main auxiliary fan is not running.

3.4.1 Line Brattice

Brattice cloths are made of fire-resistant burlap material and are usually erected or hung longitudinally from posts, crosspieces or spads or hangers in the roof in an entry often starting from the last through cross-cut to within a few meters from the face and effectively divide the opening into two. All the intake air stream is directed to the face along one side of the brattice and the return air through the other side [24]. This means that series ventilation system is being employed in workings with line brattice systems. Fig. 3 - 1 shows a typical development face where line brattice is employed to direct fresh air to the face.

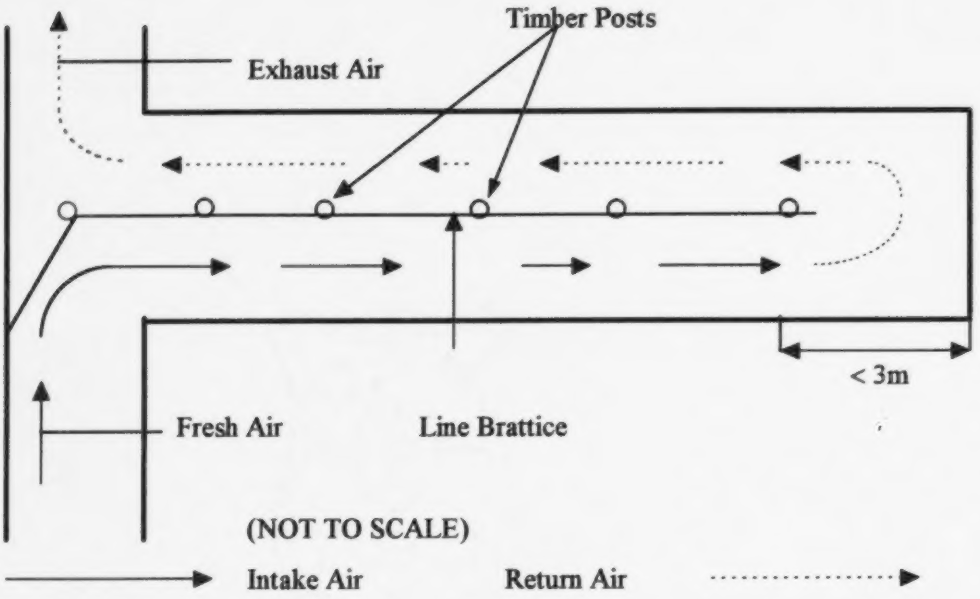


Fig. 3 - 1 Brattice Cloth Ventilation System for a Single Development Heading.

The efficiency of line brattice systems is a function of four basic factors [26]:

1) The method of ventilation (whether forcing or exhausting). Forcing brattice systems are more efficient than exhaust systems and exhaust systems require higher operating pressures than equivalent blowing systems.
2) The method of installation. Carefully installed brattice systems are more efficient than poorly installed ones.
3) The quality of the fabric used. The efficiency of line brattice systems increases with decreasing fabric porosity.
4) Narrow intake area. The efficiency of a line brattice system is known to increase with increase in cross-sectional area of the intake side of the brattice.

The main disadvantages with line brattice are that it impedes or restricts the movement of mobile mining equipment and also leaks air badly even with the best installation. Line brattice is thus incapable of delivering the required air quantities to faces requiring large quantities of fresh air (e. g. where there are high methane emission rates or a heading machine is cutting coal), and are often replaced by a fan and ducting. In spite of its inherent drawbacks, brattice cloths are still widely employed in many coal mines in the U. S. because of its low cost, ease of handling and installation. The system efficiencies for well-installed brattice systems over 30 m (100 ft) in length have been estimated to range between 30 and 70% [26].

3.4.2 Methods Employing Main Ventilation Pressure Head

Where the pressure head in the mine is high, it is possible to employ it for auxiliary ventilation by carrying ductings through doors [25]. (Figs. 3 - 2 and 3 - 3). The prevailing mine pressure head may also be employed in conjunction with either a forcing or an exhausting fan (Figs. 3 - 4 and 3 - 5). In such situations the main pressure head provides a backup in emergencies (power cut-offs) and at non-working times of the day.

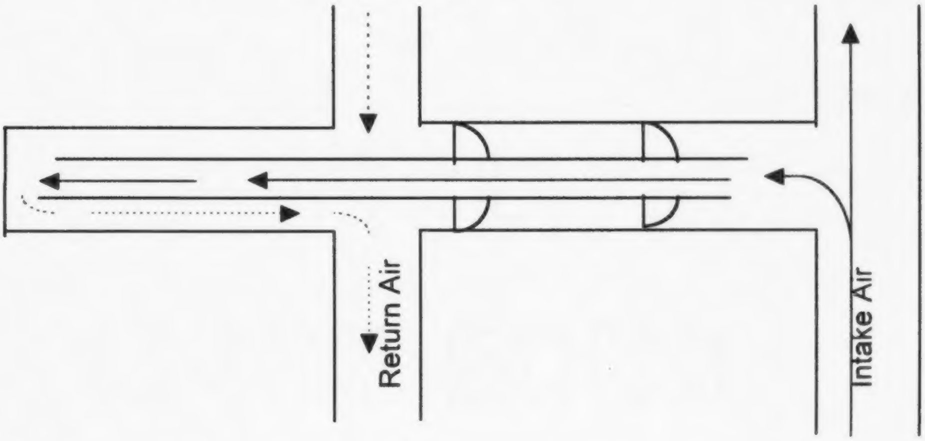


Fig. 3 - 2 **Forcing Ventilation By Mine Pressure Head**

3.4.3 Dynamic Systems

Dynamic systems are those that have components with moving parts in them. These normally comprise either forcing or exhausting fans. Tables 3 - 1 and 3 - 2 show how the velocities from the discharge end of ductings (for both a forcing and an exhausting fan) and line brattice vary with distance.

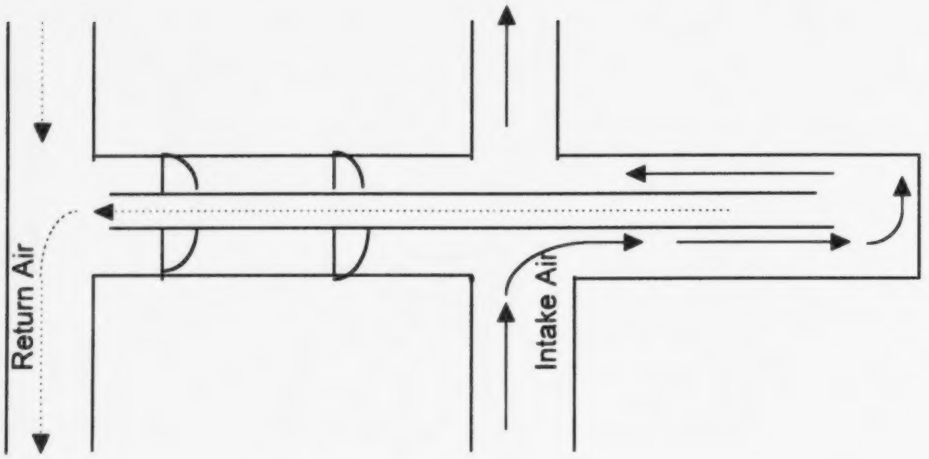

Return Air
Intake Air

Fig. 3 - 3 Exhausting Ventilation By Mine Pressure Head

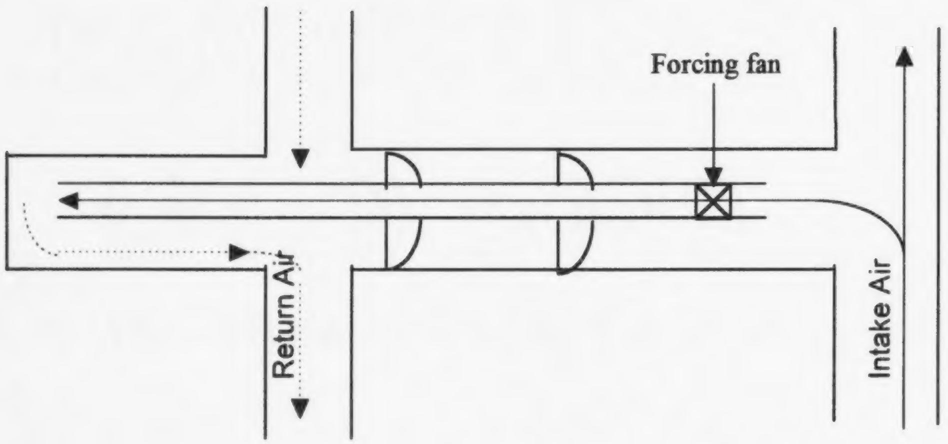

Forcing fan
Return Air
Intake Air

Fig. 3 - 4 Forcing Pressure System Available when Forcing Fan Stops

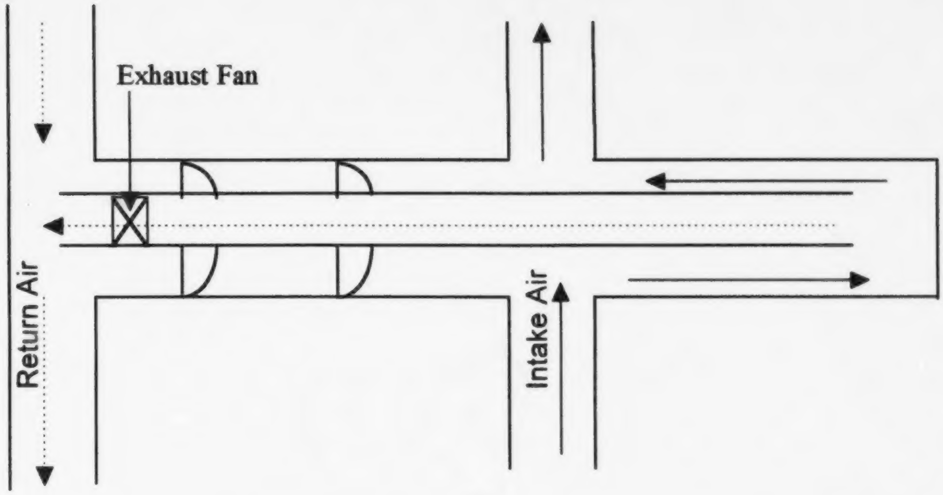


Fig. 3 - 5 **Exhausting Pressure System Available when Exhausting Fan Stops**

Table 3 -1 Diminishing Air Velocity with Distance from End of Ventilation Pipe 300 mm (12 in.) in Diameter

Blower		Exhaust	
Distance (diameters)	Velocity (% of V at pipe)	Distance (diameters)	Velocity (% of V at pipe)
5	95	0.25	60
10	60	0.50	27
25	15	0.75	14
35	5	1	7

Source: McElroy (1943), Dalla Valle (1952)

Table 3 - 2 Diminishing Air Velocity with Distance from End of a Blowing Brattice with 1.016 m/s (200 fpm) Velocity.

Distance m (ft)	Velocity (% of V at brattice)	Velocity m/s (fpm)
1.5 (5)	50	0.508 (100)
3.1 (10)	25	0.254 (50)
7.6 (25)	10	0.102 (20)

Source: Anon. (1959)

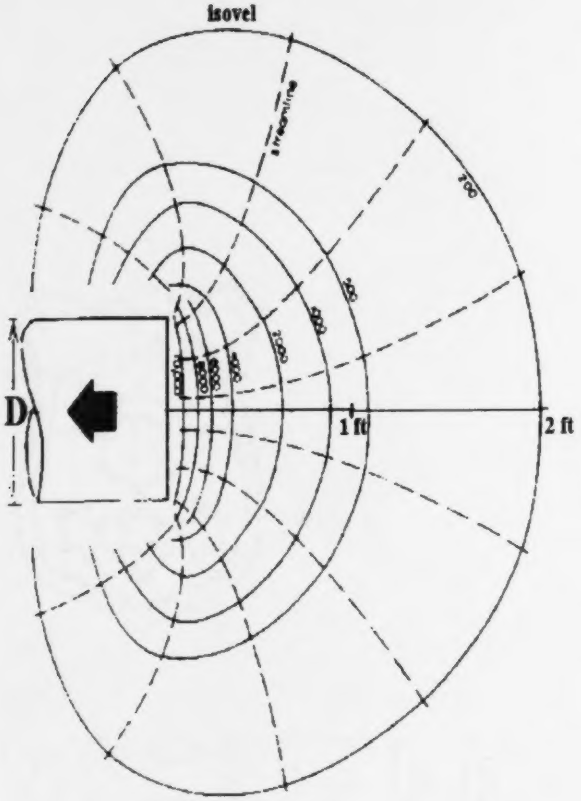

isovel
streamline
2000
D
1 ft
2 ft

Fig. 3 - 6 Airflow Patterns for Vent Tubing at the Intake of an Exhausting System

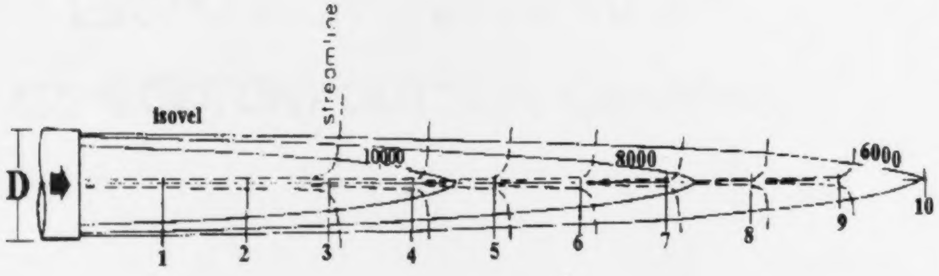

streamline
isovel
D
10000
8000
6000
1
2
3
4
5
6
7
8
9
10

Fig. 3 - 7 **Airflow Pattern for Ventilation Tubing at the Discharge of a Blower System.**

Source: McElroy (1943), Dalla Valle (1952) and Hartman (1962)

.1 Primary Forcing Systems

This system employs either a rigid or flexible ducting in conjunction with a blowing or forcing fan. A continuous positive pressure is developed by the fan in the duct which forces the air through the ducting towards and across the face and out of the working place. Fig. 3 - 8 shows a typical forcing system in a development heading. The ventilation airstream emanating from the end of the duct scours the face, dilutes and removes any methane and dust from the face of the heading. To prevent vitiated air which flows out of the drive end from entering the duct and being recirculated to the face, the intake to the duct is required to extend well (at least 5 m) into the upstream portion of the fresh air and the discharge end should be within 10 m of the face [8].

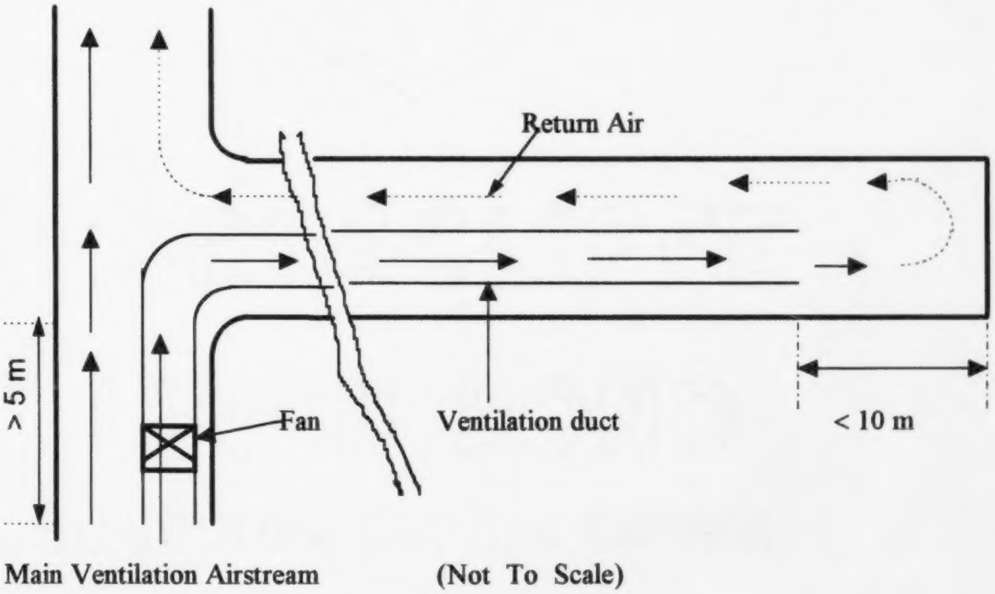


Fig. 3 - 8 Primary Forcing System in a Development Heading

The exhaust ventilation system has several advantages which include:

1. the return air is passed through a ducting and does not come into contact with electrical equipment in the heading;

2. is more efficient in controlling dust at the face during cutting of the heading machine and men enter and work in fresh air in the heading.

However, the main drawbacks in the exhaust system are that it can only be employed with rigid or reinforced ductings which are costlier, more difficult to transport and install than flexible ductings; it is ineffective in removing gases from faces that are two or more duct diameters away from the intake of the ducting (Fig. 3 - 6); heat, methane and other contaminants from outbye lengths of the heading are taken to the face which is the area of maximum activity; some of the fresh air along the heading tends to enter the exhaust ventilation duct and only a small proportion of the intake air reaches the face; any air leakage from the system is completely wasted and the fan motors have to be housed out of the airstream.

Among the many advantages of the system cited [20, 24] are:

1. it allows the use of flexible ducting (which has a lower cost and is easy to transport and install).
2. intake air takes up less heat and moisture from the surrounding strata and ambient air before it reaches the face of the heading and thus provides a cooler atmosphere.
3. has higher velocities at longer distances from the discharge end of the duct.
4. the fan handles fresh air (motor can be located in the air stream).
5. any air leakage is not completely wasted.

However, the forcing system has the followin inherent disadvantages:

1. men working and traveling in the drive are exposed to all the dust and gases produced during the shotfiring and when the heading machine is cutting
2. the higher velocity air streams at the face tend to pick up and disperse dust into the body of the return air.

.2 Exhausting Systems

This system employs either rigid or spiral wire reinforced ducting as it does not collapse under the negative pressures inherent with the system. The exhausting system provides a continuous negative pressure in the ducting system, takes its supply of air from the mine opening and removes it from the face through a duct [22, 27]. In order to be effective the inlet of the duct must be as close as possible to the face of the heading [< 2 m (6 ft)]. Fig. 3 - 9 shows a typical exhausting system in a development heading. The discharge end of the exhaust ducting is required to extend at least 5 m (15 ft) beyond the entrance of the drive end on the downstream side to prevent vitiated air from re-entering the drive [4].

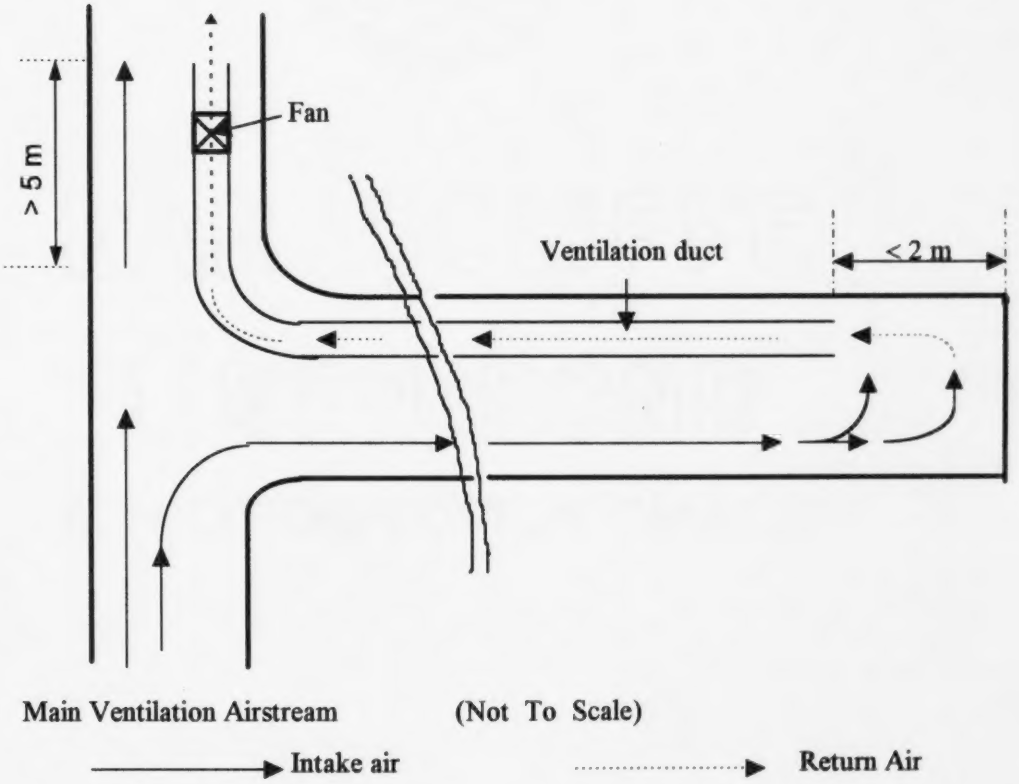

Fan
> 5 m
Ventilation duct
< 2 m
Main Ventilation Airstream
(Not To Scale)
Intake air
Return Air

Fig. 3 - 9 Primary Exhausting System in a Development Heading

The exhaust ventilation system has several advantages which include:

1. the return air is passed through a ducting and does not come into contact with electrical equipment in the heading;
2. is more efficient in controlling dust at the face during cutting of the heading machine and men enter and work in fresh air in the heading.

However, the main drawbacks in the exhaust system are that it can only be employed with rigid or reinforced ductings which are costlier, more difficult to transport and install than flexible ductings; it is ineffective in removing gases from faces that are two or more duct diameters away from the intake of the ducting (Fig. 3 - 6); heat, methane and other contaminants from outbye lengths of the heading are taken to the face which is the area of maximum activity; some of the fresh air along the heading tends to enter the exhaust ventilation duct and only a small proportion of the intake air reaches the face; any air leakage from the system is completely wasted and the fan motors have to be housed out of the airstream.

3.4.4 Overlap Ventilation Systems in Development Headings

The overlap systems combine the inherent advantages of the forcing and exhausting systems. The main overlap systems (discussed later in this section) are:

1. a primary forcing system with a secondary exhaust overlap.
2. a primary exhausting system with a secondary forcing overlap.

The main advantage of the overlap systems is that they are generally more efficient in controlling contaminants at the face. For example in a development heading where the primary forcing with secondary exhaust overlap system is employed, the forcing system effectively controls the gases emitted at the face while the respirable dust produced by the cutting machine is conducted away from the face by the exhaust overlap ducting leading to a fan and a dust filter.

The drawbacks associated with the overlap system include reductions in the air velocity in the overlap zone; the overlap fan can only take a limited quantity of air (less than the quantity of the primary fan) to avoid recirculation of air within the drive; requires close monitoring of the length of overlap in order to maintain good air velocity at the face and to avoid possible recirculation of air; it is more costly since it requires two separate columns of ductings each with one or more fans; require that the overlap fan(s) be interlocked with main auxiliary fan to avoid the overlap fan(s) running after the main fan has stopped (*as this would cause recirculation of air in the heading which could be dangerous*).

.1 Primary Forcing System with Exhaust Overlap

Fig. 3 - 10 shows the system. It incorporates the advantages of the forcing and exhaust systems. The forcing system is usually located on the same side of the drive as the continuous miner (CM) or roadheader (RH) operator to supply fresh air to him and to blow dust away from him. The end of the overlap is kept as close as practicable to the face of the heading for effective dust and gas extraction. The overlap fan is often mounted on the heading machine [CM or tunnel boring machine (TBM)], suspended from a monorail or mounted on a bogie and pulled forward by the heading machine. Systems with the exhaust overlap mounted on the heading machine are preferable because the duct entry is always at a fixed distance and close to the face [24].

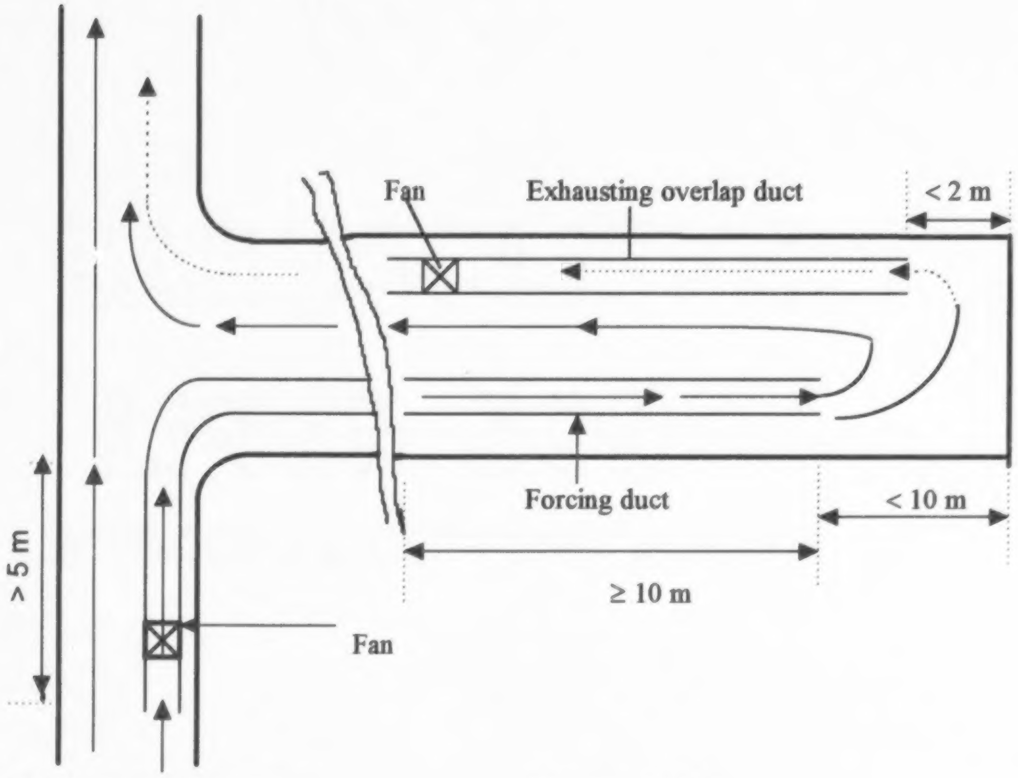
.2 Primary Exhaust System With Forcing Overlap

Fig. 3 - 11 shows the main exhaust system with forcing overlap duct. It combines the advantages of the forcing system with the scouring action of the face by air projected by the secondary forcing system and some of the return air can be pre-cleaned by a dust collector in the overlap.

The use of auxiliary fans and ducting is the best way to ventilate a dead-end working area. When properly installed and maintained, a fan and ducting will deliver more air over a given distance with greater velocity. Compared to line brattice, a fan and ducting combination is more compact allowing more room for production equipment to pass. Compressed air (using venturis) may also be employed in auxiliary ventilation [24] though this practice is not widely used because it is costly and has a very limited capacity.

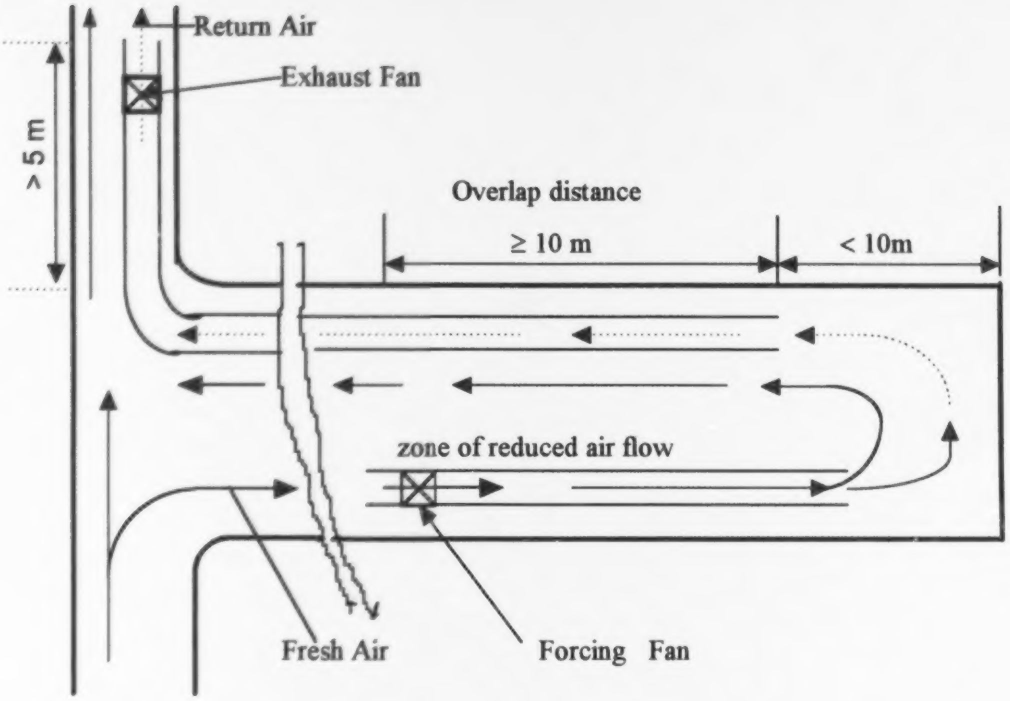
3.5 Types of Auxiliary Ventilation Fans

The types of fans used in auxiliary ventilation systems are in-line radial flow fans, in-line axial flow fans or bifurcated axial flow fans [27]. In auxiliary ventilation systems involving a fan and ducting, the auxiliary fan must provide sufficient head not only to supply air to the face through the duct but also to return it to the main ventilation airstream through the mine opening. The head of the fan must therefore overcome the pressure losses in both the duct and return mine opening [27]. However, as the quantity of flow is usually small and the size of the opening in relation to the duct is very large, the head required for the return airflow is usually very small and is often neglected in calculations of fan head requirements.



(Not To Scale)

Fig. 3 - 10 Primary Forcing System with Exhaust Overlap



Main Ventilation Airstream (Not To Scale)

Fig. 3 - 11 Primary Exhaust System with Forcing Overlap

In-line radial flow fans (Fig. 3 - 12) are essentially centrifugal fans in which the air current that enters the fan is turned through 90° with the impeller. The air is again turned through another 90° to flow over the bifurcated fan casing before exiting the fan at the discharge end. The motor is usually mounted out of the airstream in a pod.

Unlike, in-line radial fans, in-line axial flow fans (Fig. 3 - 13) have the motor mounted in the airstream behind the impeller and employ guide vanes to impart a swirl or counter-swirl to the air so that it flows axially through the fan.

A bifurcated axial flow fan (Fig. 3 - 14) has its motor mounted outside the airstream within a pod and the air flows along the bifurcated trunking of the casing. Bifurcation essentially seals off the fan motor in an enclosure within the fan preventing the air from flowing over the electrical coils and connections. All auxiliary fans are generally grounded to the earth to prevent any electrostatic charge from building up to unsafe levels.

The volumetric capacities of auxiliary fans studied range from 2.36 to 14.16 m^3/s (5,000 to 30,000 cfm) at up to 3.75 kPa (15 in. w. g.).

3.5.1 Sizes of Axial Flow Fans.

The general types of axial flow fans used are [28]:

1. Model A20, 508 mm diameter, 4.0 kW in-line fan
2. Model A40, 610 mm diameter, 18 kW in-line fan
3. Model A70, 760 mm diameter, 37 kW in-line fan
4. Model B20, 508 mm diameter, 7.64 kW bifurcated fan
5. Model B40, 610 mm diameter, 18 kW bifurcated fan
6. Model B70, 760 mm. diameter, 37 kW bifurcated fan

The efficiency of the in-line fan is superior to the bifurcated fan, but in the exhausting systems the isolation of the bifurcated fan motor from the ducting air can be an overriding consideration.

3.5.2 Sizes of Radial Flow Fans

Sizes employed include [28]:

- Model BC40, 610 mm diameter, 18 kW bifurcated fan
- Model BC70, 760 mm diameter, 37 kW bifurcated fan
- Model BC90, 900 mm diameter, 90 kW bifurcated fan

3.6 Fan Laws

Fan characteristic curves {*which are plots of the pressure heads (static or total), fan efficiency and power as a function of air quantity flowing through the fan*} can be employed to predict the behavior of a fan under changing head-quantity conditions. In order to calculate the ventilation requirements of a particular ventilation system in a mine opening, it is necessary to calculate the fan capacities and efficiencies.

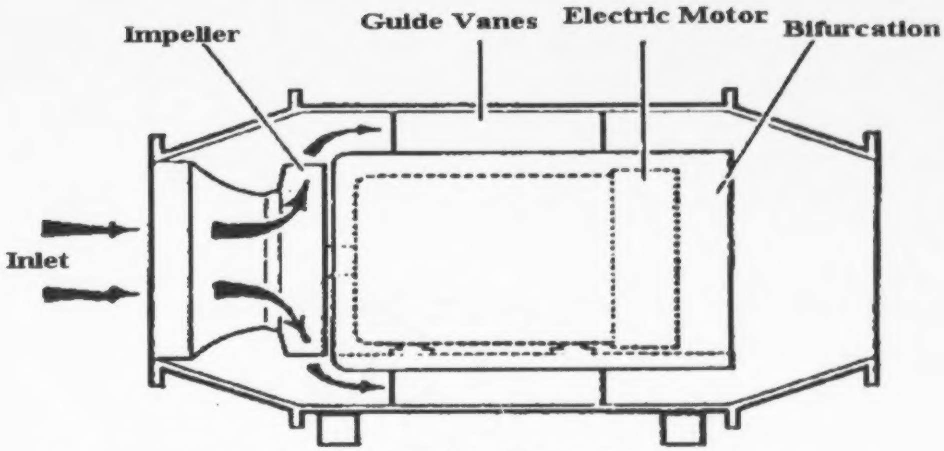

Impeller
Guide Vanes
Electric Motor
Bifurcation
Inlet

Fig. 3 - 12 An In-line Radial Flow Fan

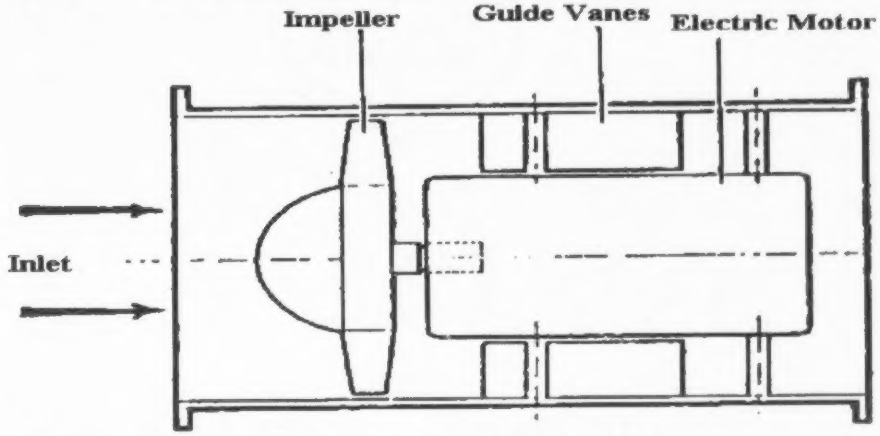

Impeller
Guide Vanes
Electric Motor
Inlet

Fig. 3 - 13 An In-line Axial Flow Fan

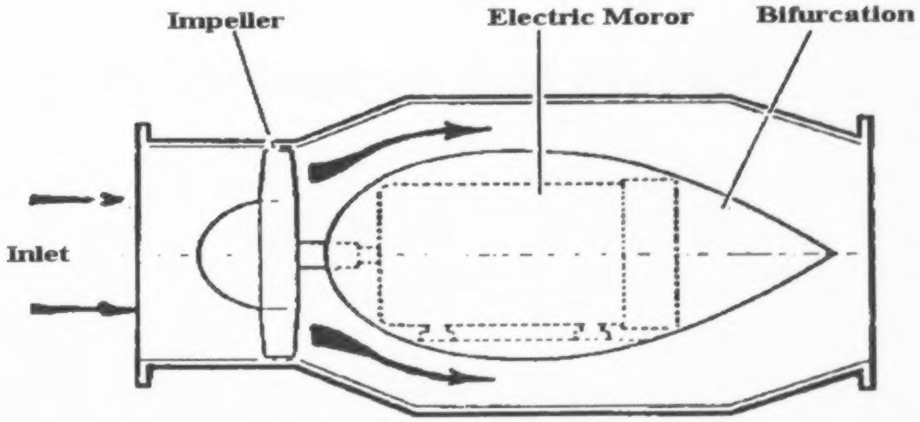

Impeller
Electric Moror
Bifurcation
Inlet

Fig. 3 - 14 A Bifurcated In-line Axial Flow Fan
Source: Anon. (1986)

This can be done using the fan laws. The fan laws for a range of geometrically similar fans and for a particular point of operation on the head-quantity characteristic are [1, 4]:

Volume flow rate, $Q \propto n\,D^3$ (m^3/s) (3 -1)

Fan pressure, $P \propto n^2 D^2 \omega$ (Pa) (3 - 2)

Fan power, $W \propto n^3 D^5 \omega$ (kW) (3 - 3)

where n = speed of rotation

D = impeller diameter, m

ω = air density, kg/m^3

3.7 Types of Ventilation Ductings

The efficiency of the auxiliary ventilation system also depends primarily on the length of duct, the correct matching of the fan to duct diameters and on the quality of installation. Underground auxiliary ductings have to be well-installed and maintained to avoid excessive leakage of air (leading to high pressure losses) and inadequate quantities of air delivered to the face of the heading. The effects of these on the efficiencies of the various auxiliary ventilation systems are treated in depth in Chapter 4.

The main types of ventilation ducting employed in coal mines are rigid, flexible and flexible wire reinforced ductings.

Rigid ductings are generally made of either metal or fiber glass. They have very good resistance-pressure loss characteristics, last longer and have lower maintenance costs. They are made in diameters ranging from 300 to 1219 mm (12 to 48 in) and in lengths of 2 to 4 m. They are however bulky, difficult to handle and install; generally leak at the joints except where adequate gaskets are employed at the joints and the steel ducts easily rust in wet conditions. Fiberglass ducts are lighter in weight, have excellent air resistance characteristics (*about 12% less resistance to airflow than corrugated metal ducts of same dimensions)* and have excellent resistance to the corrosive effects of acid and alkaline mine water but have the same leakage problems as the metallic ductings.

Flexible ventilation ductings are made from vinyl laminated or coated fabrics, are low in cost and are easy to transport and install. They are made in the same diameters as rigid ductings. Common lengths are range from 4 to 15 m to allow the ducting to be folded or collapsed and tied into small bundles to facilitate transportation [28]. When properly installed they have low resistance characteristics but this is still higher than those of rigid ductings. They are highly susceptible to damage from moving equipment, have shorter lifespans than rigid ductings and cannot be used with exhaust ventilation systems.

Flexible wire reinforced ductings are made of the same material as the flexible ductings but have a spiral wire embedded in them. The varying wire diameter or pitch of the spiral determine the amount of suction the duct can withstand before collapsing. These are normally available in lengths up to 6 m. They have similar advantages and drawbacks as the flexible ductings except that they can be employed in both forcing and low-pressure exhausting systems. Unless stretched tightly during installation [23] they have poor resistance characteristics.

In some coal mines the material used in manufacturing ventilation ductings is required to meet fire resistance and antistatic requirements.

3.7.1 Factors Affecting Delivery of Air through Ductings

Due to the nature of the ductings, their age, standard of installation and the numerous joints, it is practically impossible to completely eliminate the leakage of air from and into the ducting. Therefore certain parameters that affect the delivery of air through ductings are usually employed to assess the efficiency of the air delivery system through the ductings. Some of these parameters are Leakage coefficient (LC), Pressure loss in leakless ducting and Correction factor (CF).

.1 Leakage Coefficient (LC)

This is a measure of the leakage of a ducting [28] and it is defined as the volume of air in cubic meters per second (ft^3/min.) which would leak from 30.3 m (100 ft) of ducting under a uniform pressure of 2.54 cm (1 inch) of water. Leakage coefficients have been allocated arbitrary values as Very good (0 - 50 LC); Good (50 - 100 LC) and Average (100 - 200 LC).

.2 Pressure Loss in a Leakless Ducting

This is the pressure loss involved in air flow through mine ductings and can either be obtained from standard graphs or calculated.

.3 Correction Factor (CF)

This relates to the actual length of ducting in the form:

$$CF = \frac{Q_i}{Q_d} \tag{3 - 1}$$

where CF = Correction Factor

Q_i = Quantity of airflow at fan intake, m^3/s

Q_d = Quantity of air discharged at the face, m^3/s

For CF $\leq$ 3, the CF approximates to the ratio of the pressure required to deliver a quantity of air through the actual duct to the pressure required to deliver the same quantity through a leakless duct [28].

3.8 Airflow Analysis in Leaky Ducts

Where leakages through a ducting are known to exist, three methods are employed in analyzing the airflow problems through the leaky duct [4]:

- mathematical analysis of the airflow assuming that the leakage is uniformly distributed.
- analysis on the assumption that there exists a number of discrete leakage points along the duct and treating these over the entire leaky duct as if it were a ventilation network.
- assuming a number of discrete leakage paths and treating the airflow through the leakage duct as a series-parallel combination of airflows along the duct and through the leakage paths.

The pressure loss along a ventilation ducting varies with [29] the resistance per unit length, R (Ns^2/m^8), the quantity of air flowing through the ducting, Q (m^3/s) and the length of the ducting, L (m).

The pressure loss along a ventilation ducting may be calculated from the following relation [29]:

$$dP = R \times Q^2 \times dL \qquad \text{(kPa)} \qquad (3-2)$$

The amount of leakage occurring at any point in a ventilation ducting may be calculated from the following expression:

$$dQ = LC \times P \times \gamma \times dL \qquad (m^3/s) \qquad (3-3)$$

where dQ = Leakage quantity through the ducting, m^3/s

P = Pressure at point of leakage, (kPa)

LC = Leakage coefficient

dL = change in distance along ducting, m

γ = a constant whose value depends on the state of flow of the fluid (if flow is turbulent, $\gamma = 0.5$; if flow is laminar, $\gamma = 1.0$ [29].

Various empirical mathematical relations and models have been formulated and computer programs and software developed for quick analysis of airflow problems through leaky ductings [4, 29].

In the analysis of airflow through ductings, a number of assumptions are usually made which include:

1) that the air density is constant throughout the flow system.
2) the leakage is independent of the velocity pressure.
3) losses in pressure at the end of the ducting are neglected.
4) that the diameter of the ducting is uniform throughout the full length and
5) that velocity pressure in the air leaving the fan is very small compared with the total pressure.

Mine ventilation software developed along the lines of the foregoing equations are employed later in Chapter Four in the calculation of leakages through ductings, static pressure losses in the ducting, etc.

Chapter Four

DATA ANALYSIS

4.1 Introduction

This section summarizes the results of the last two phases in this work: a survey of the prevailing auxiliary ventilation systems being employed in selected coal mines in North America by means of questionnaires and on-site mine visits. Chapters 1 to 3 covered the literature search done in phase 1. The results obtained from the questionnaires, methane concentration monitoring at the faces of development headings and tracer gas based tests conducted to assess the efficiencies and effectiveness of the auxiliary ventilation systems in the mine roadways are detailed and discussed in this chapter.

4.1.1 Results of Mine Survey from Questionnaires

As part of the study, 165 questionnaires were sent out to selected operating coal mining companies in North America to survey the prevailing mining, ventilation methods and techniques adopted in dealing with methane gas in mine headings. The outcome of this survey was very poor as only 8 mines returned their completed questionnaires for analysis. For the purpose of safeguarding the identity of the mines concerned in this report, the mines are labeled as Mines 1 to 8. As is typical of all surveys from questionnaires, it is not possible to cross-validate the figures and information received. Notwithstanding this fact, the following useful information was obtained (Appendices A - 1 to A - 4):

1. The predominant mining methods employed were room-and-pillar method with or without pillar recovery and longwall or shortwall methods in either advancing or retreating order.
2. Most mines employed continuous miners and roadheaders (of Joy, Jeffrey, Alpine or Dosco manufacture) in combination with either belt conveyors or 2 or 3 shuttle cars at the development headings.

3. The depths of the workings ranged from 45 to about 700 m below surface with seam thicknesses of 1.2 to 3.5 m. (Appendix A - 1).
4. Production capacities at the headings varied from 30 to 1455 tonnes/shift in main drivages with average advance rates in the range of 2 to 92 m/shift.
5. The methane concentration in the general body of the return air ranged from trace to 0.6% by volume of air.

4.1.2 Mine Visits

On-site mine visits were made to all the operating underground coal mines in Canada to conduct air quantity and methane concentration measurements. The mine headings studied are labeled as Headings 1 to 22 for confidentiality.

In order to assess the efficiencies of any ventilation system, it was necessary to measure the various parameters of the mine atmosphere. These parameters included pressure, volume and temperature-humidity surveys as well as the monitoring of methane gas concentrations mainly in development headings and roadways by means of either continuous methane monitors or with handheld methanometers.

Air velocity and hence air quantity surveys were mainly done with vane anemometers, pitot tubes, velometers or by tracer gas based techniques [31]. The results of methane concentration monitoring at a number of development headings, evaluations of the auxiliary ventilation systems through the ducting using sulphur hexafluoride (*used as a tracer gas*) and face ventilation tests by means of a light bulb filled with tracer gas (point release) are detailed later in this chapter.

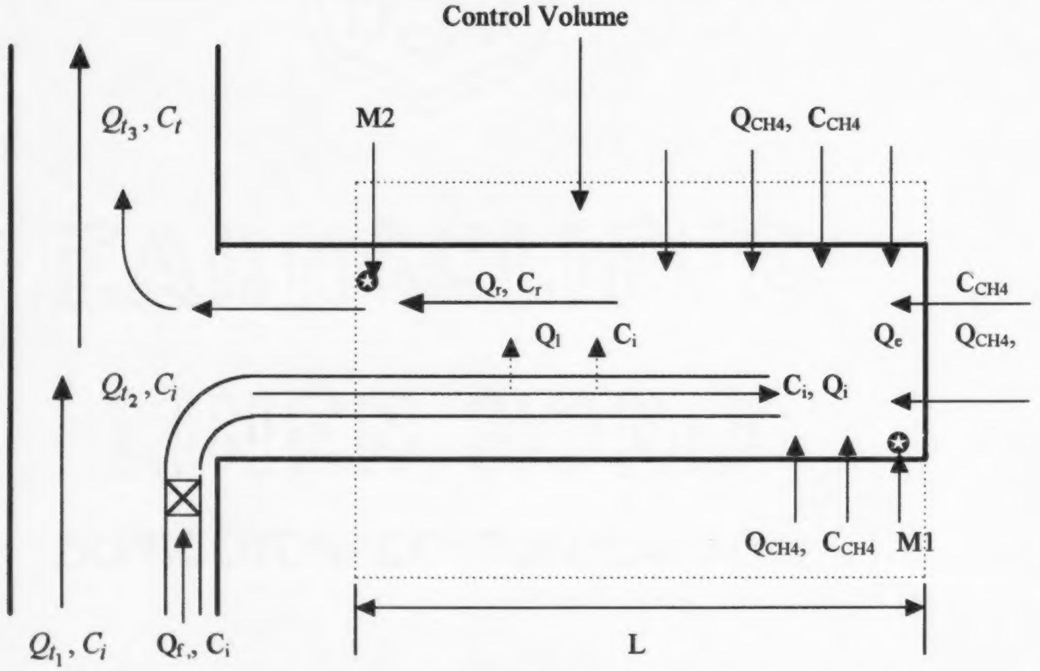
4.2 Auxiliary Ventilation System Performance

In evaluating and assessing the efficiencies of the existing auxiliary ventilation systems in mine headings, the following assumptions were made in the calculations:

1. The air flow within the headings and at the faces is fully turbulent and an unsteady state condition exists at the start of the cutting operation (as communition of the coal takes place and the free gas is released into the

heading) but this stabilizes with time to a steady state (*when no cutting is taking place*); the methane and other gases desorbed from the strata are thoroughly mixed with the air in the heading.

2. A certain portion of the heading close to the face, called the control volume, (*the excavated area enclosed by the broken line in Fig. 4 - 1*), is considered as the zone of mixing and dilution of gases in the analysis. This control volume is defined as the volume of the heading between the face and a point outbye (*at least 60 m from the face*) at the end of the overlap system where steady state flow has been reached. The volume of the room was taken as if there were no equipment in it.


Control Volume
Q_{t_3}, C_t
M2
Q_{CH4}, C_{CH4}
Q_r, C_r
Q_l
C_i
Q_e
C_{CH4}
Q_{CH4},
Q_{t_2}, C_i
C_i, Q_i
Q_{CH4}, C_{CH4}
M1
Q_{t_1}, C_i
Q_f, C_i
L

✪ M1 - Continuous Methane Monitor at Face

✪ M2 - Continuous Methane Monitor in Return

(NOT TO SCALE)

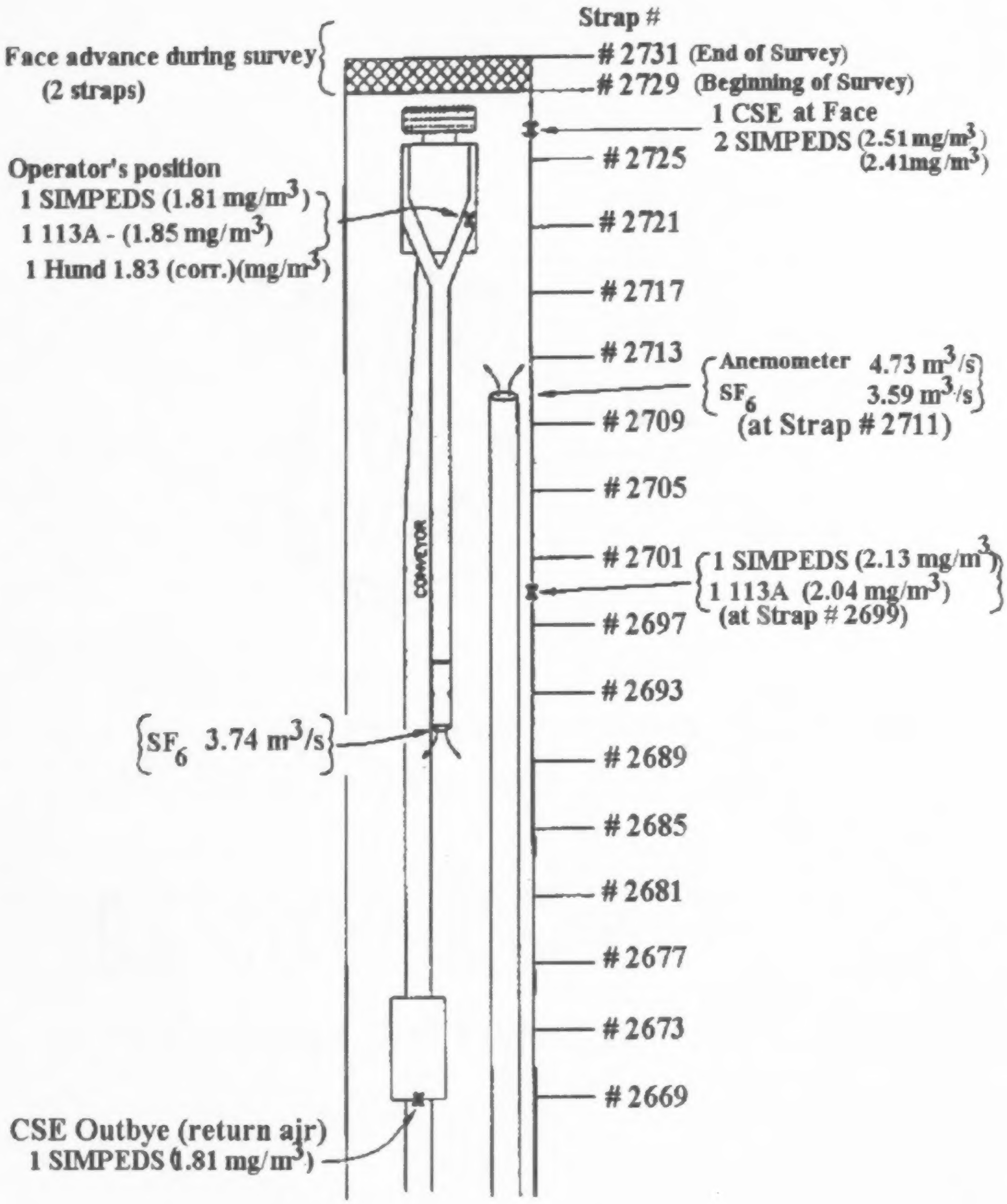
Fig. 4 - 1 Schematic of Air Flow Parameters in a Mine Development Roadway.

3. The methane emitted from the seams and strata (although it is subjected to some level of dilution once out of the pores and fissures of the coal) is assumed to be pure (100%) in concentration by volume.
4. Most of the methane (*at least 95%)* emitted within a heading is from the freshly cut face area alone. This introduces a small error as some of the methane is also known to originate from the sides of headings and from pillars long after the heading has advanced beyond those points [3, 21, 32].
5. There is no recirculation of air within the heading.

4.2.1 Methane Concentration Monitoring at Development Headings

Ideally, in order to effectively monitor the concentration of any gas at a working face it is necessary to have as many gas detectors as possible at many positions along the working. This is to take care of the differences in buoyancy and flow conditions of the constituent gases in the mine air or the uneven mixing of the gases and hence the varying concentrations of the gases along the working. This would not only be very costly from the logistical point of view (high equipment costs, etc.) but would be practically difficult to implement without interrupting and interfering with the normal production activities at the workings.

Due to the limited number of continuous methane monitors available for use in this work, it was possible to monitor the concentration of methane at only two stations simultaneously. Handheld methanometers were used to monitor methane concentrations at intermediate locations. Fig. 4 - 2 shows the plan view of a typical development heading with a continuous miner as the heading machine. The common positions of the continuous methane monitors (CSEs) in the drive are indicated. The face monitor was usually hung near the roof but on the same side as the heading machine operator and as close as possible to the face (< 1 m from the face) while the monitor in the return air was hung in the center of the heading at about 60 m from the face.


Strap #
Face advance during survey (2 straps)
# 2731 (End of Survey)
# 2729 (Beginning of Survey)
1 CSE at Face
2 SIMPEDS (2.51 mg/m3) (2.41mg/m3)
# 2725
Operator's position
1 SIMPEDS (1.81 mg/m3)
1 113A - (1.85 mg/m3)
1 Hund 1.83 (corr.)(mg/m3)
# 2721
# 2717
# 2713
Anemometer 4.73 m3/s
SF6 3.59 m3/s
(at Strap # 2711)
# 2709
# 2705
# 2701
1 SIMPEDS (2.13 mg/m3)
1 113A (2.04 mg/m3)
(at Strap # 2699)
# 2697
CONVEYOR
# 2693
SF6 3.74 m3/s
# 2689
# 2685
# 2681
# 2677
# 2673
# 2669
CSE Outbye (return air)
1 SIMPEDS (1.81 mg/m3)

{SIMPEDS, Hunds and 113A are dust measuring instruments}

Fig. 4 - 2 Plan View of a Typical Development Heading

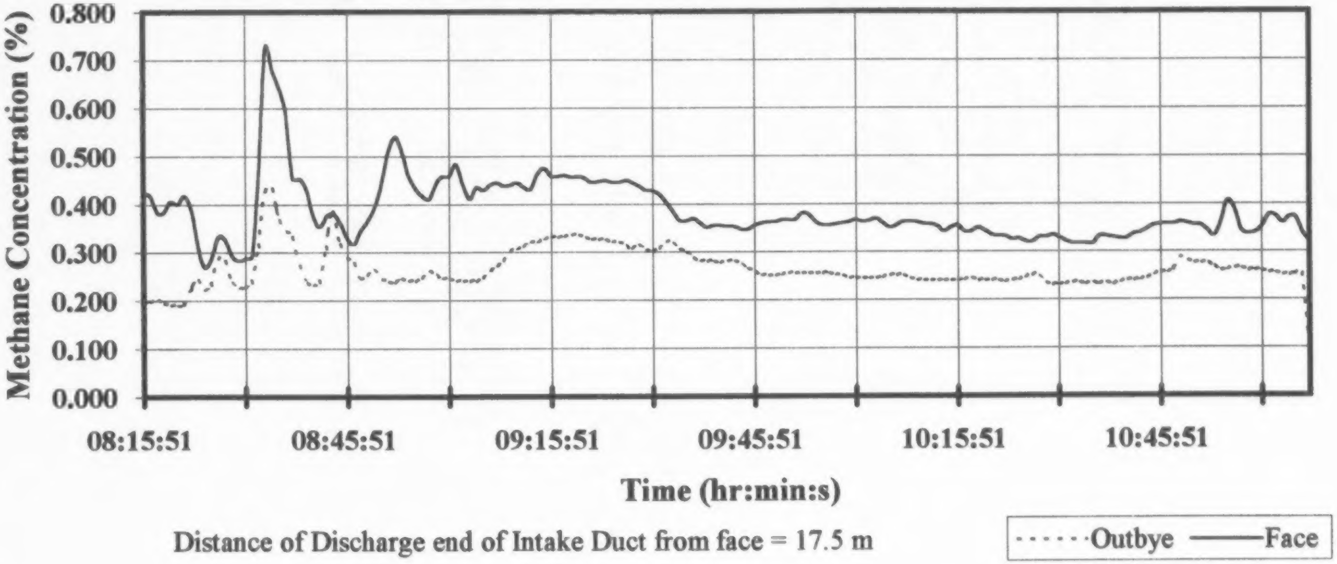
The battery powered intrinsically safe continuous methane monitors (*CSE Corporation, Model 180R which are connected to telog data loggers are capable of measuring methane concentration to 0.05% accuracy*) were usually set up as soon as possible at the start of the shift and the methane concentrations recorded at one minute intervals throughout the shift. Two readings were recorded every minute by the CSEs - the first one being the average methane concentration within that minute and the second being the maximum methane concentration reached during that minute. At the end of the shift, the monitors were taken up to the surface and the data downloaded into a computer and processed.

Figs. 4 - 3 to 4 - 13 show the variation of methane concentration with time during shift as recorded by the face and return air monitors in six different headings at various times between December 1990 and September 1994. As expected, the methane concentrations in the heading are higher when the coal is being cut (as indicated by the high peak zones in the figures) than during roofbolting operations and other activities which do not involve the communition of coal at the face. From Figs. 4 - 3 to 4 - 8, the methane concentrations recorded by the monitor at the face are usually substantially higher (about 80% higher) than those of the monitor in the return air (outbye) which gives credence to the theory that most of the methane emission in a development heading (*that is being worked*) is from the freshly cut face area [3]. The differences in the average concentrations of methane at the face and in the return is a function of the efficiency of the auxiliary ventilation system and the level of methane emission into the heading. Under a given methane inflow rate, narrow differences between the face and outbye methane concentrations are signs of an inefficient or an ineffective auxiliary ventilation system. It is also notable that while the methane concentrations at the face usually varied within wide limits (*as evidenced by the large standard deviations of the concentrations at the face in Figs. 4 - 3 to 4 - 8*), the methane concentrations in the return air were almost virtually constant throughout the shift. This shows that methane emitted at the face was effectively dispersed and diluted to normal concentrations within the control volume (volume from

Fig. 4 - 3 Relationship between Average Methane Concentration at the Face and 93 m Outbye and Time of Shift at Heading #9

Mean of Average Methane Concentrations at the Face = 0.38% Standard Deviation = 0.07%

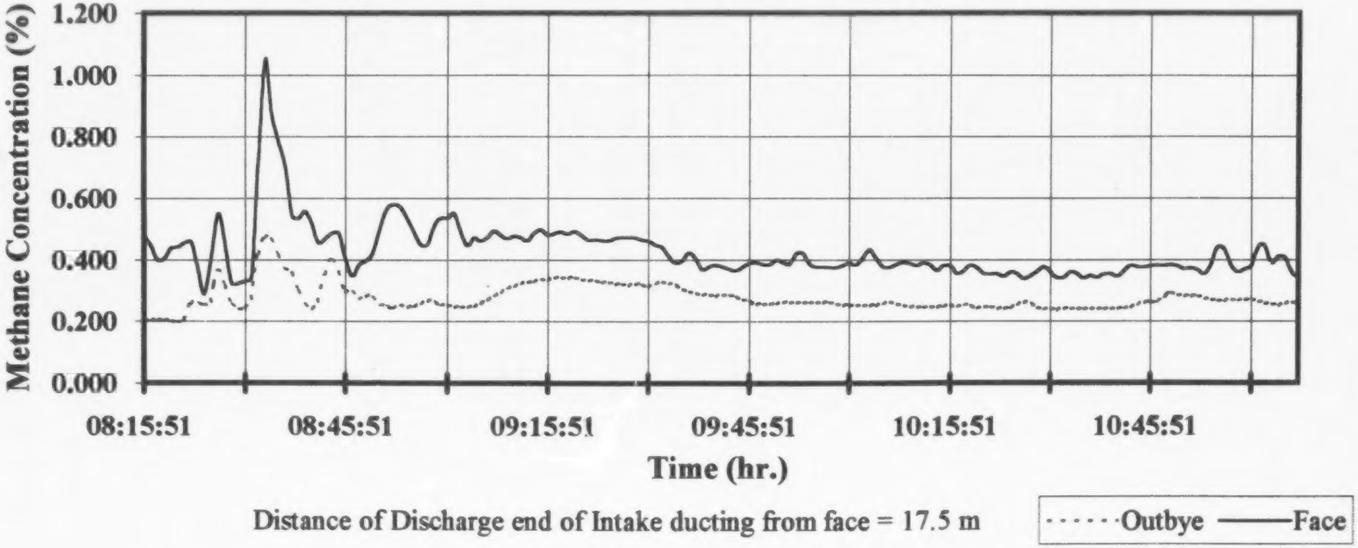
Mean of Average Methane Concentrations 93 m Outbye =0.26% Standard Deviation = 0.04%



Distance of Discharge end of Intake Duct from face = 17.5 m

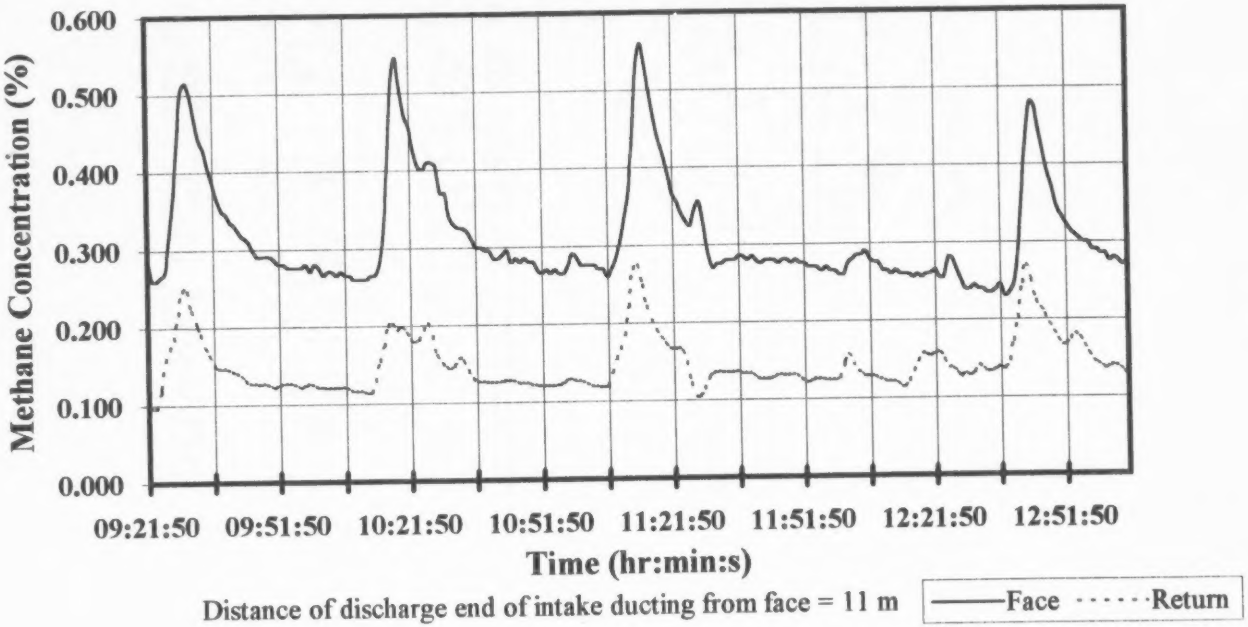
Fig. 4 - 4 Relationship between Maximum Concentration of Methane at Face and 93 m Outbye and Time of Shift at Heading #9

Mean of Maximum Methane Concentrations at the face =0.43% Standard Deviation = 0.09%
Mean of Maximum Methane Concentrations 93 m Outbye = 0.27% Standard Deviation =0.04%



Distance of Discharge end of Intake ducting from face = 17.5 m

Fig. 4 - 5 Variation of Methane Concentration at the Face and in the Return (69 m Outbye) with Time at Heading #10



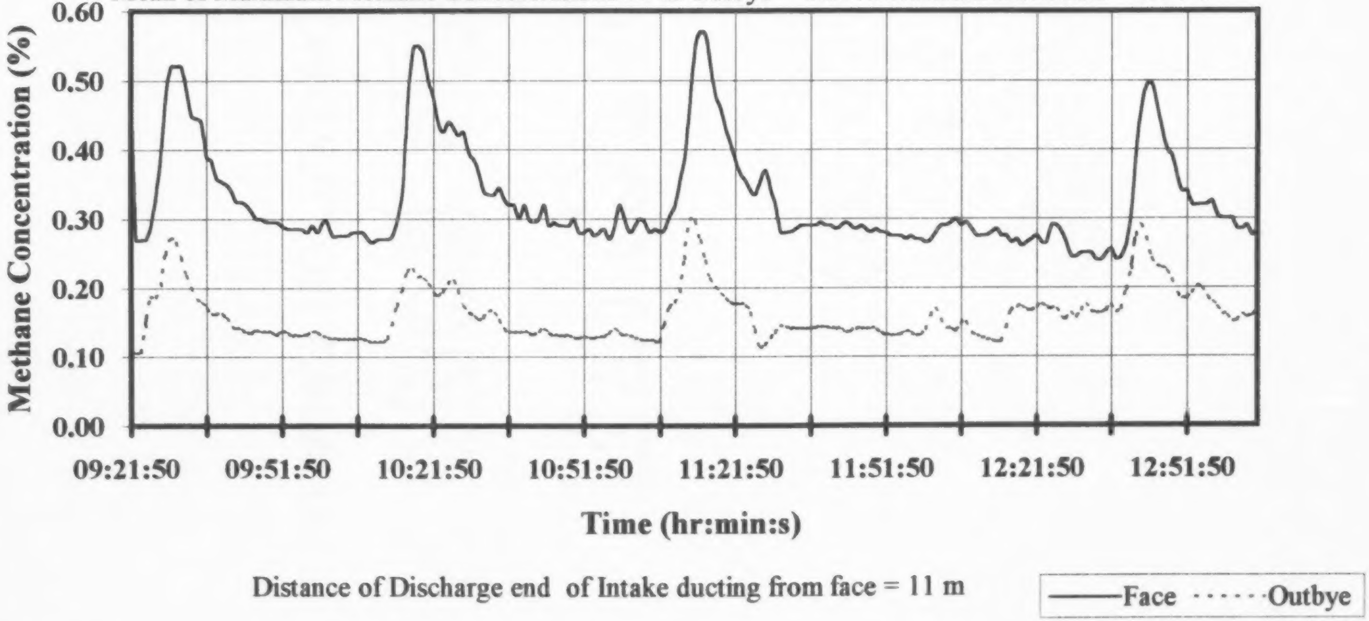
Average Methane Concentration at Face = 0.31% Standard Dev. = 0.07%

Average Methane Concentration in Return Air = 0.15% Standard Dev. = 0.03%

Distance of discharge end of intake ducting from face = 11 m

Fig. 4 - 6 Variation of Maximum Methane Concentration at the Face and Outbye with Time at Heading #10

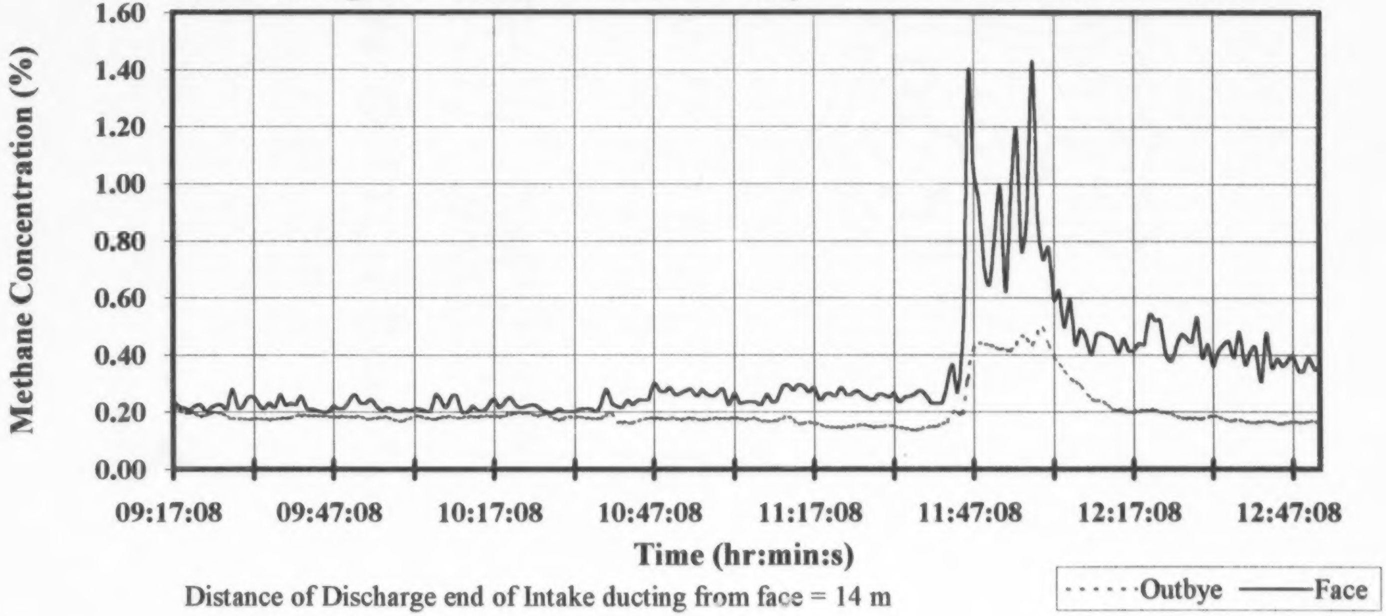
Mean of Maximum Methane Concentrations at the Face = 0.33% Standard Deviation = 0.08%
Mean of Maximum Methane Concentrations 69 m Outbye = 0.16% Standard Deviation = 0.04%



Distance of Discharge end of Intake ducting from face = 11 m

Fig. 4 - 7 Variation of Average Methane Concentrations at Face and 56 m Outbye with Time at Heading #11

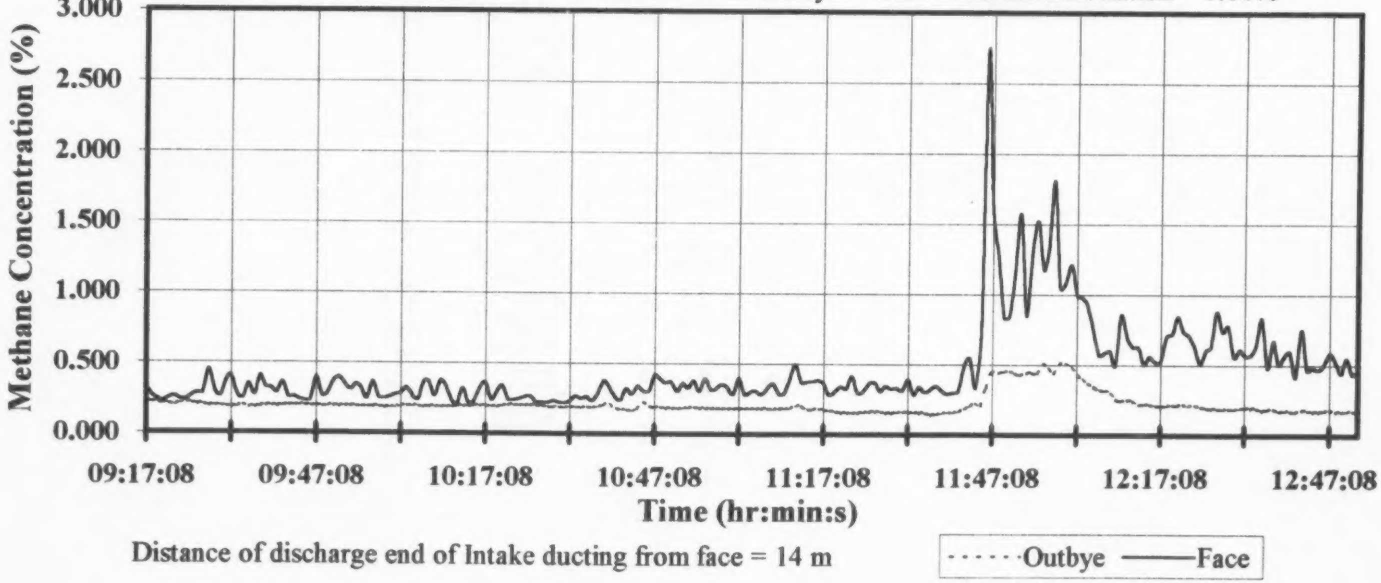
Mean of Average Methane Concentrations at the face = 0.34% Standard Deviation = 0.20%
Mean of Average Methane Concentrations 56 m Outbye = 0.20% Standard Deviation = 0.07%



Distance of Discharge end of Intake ducting from face = 14 m

Fig. 4 - 8 Variation of Maximum Methane Concentration at the Face and 56 m Outbye with Time at Heading #11

Mean of Maximum Methane Concentrations at the face =0.46% Standard Deviation = 0.32%
Mean of Maximum Methane Concentrations 56 m Outbye = 0.21% Standard Deviation = 0.08%



Distance of discharge end of Intake ducting from face = 14 m

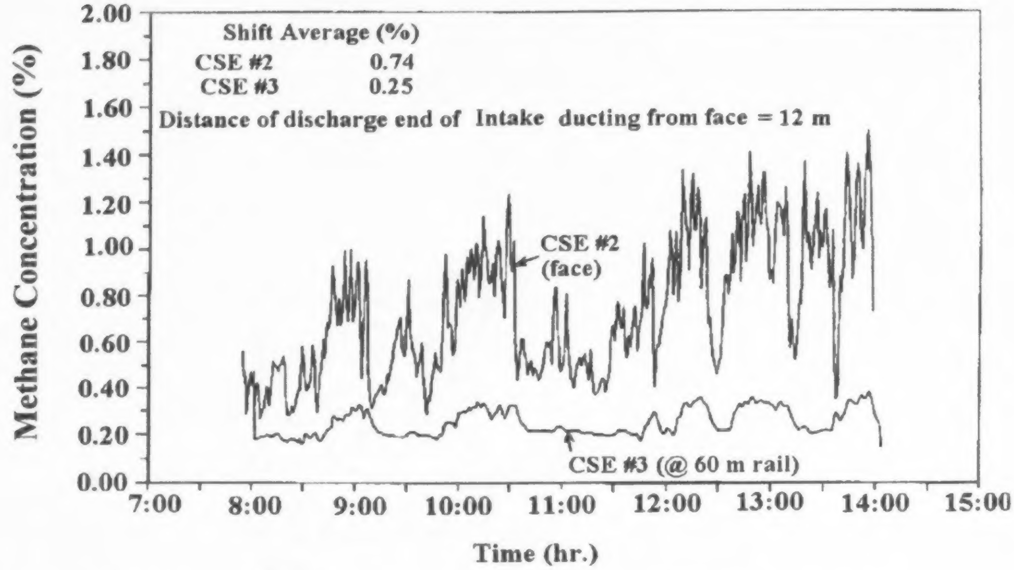


Fig. 4 - 9 Variation of Methane Concentration during Shift at Heading #4

(Dec. 13, 1990)

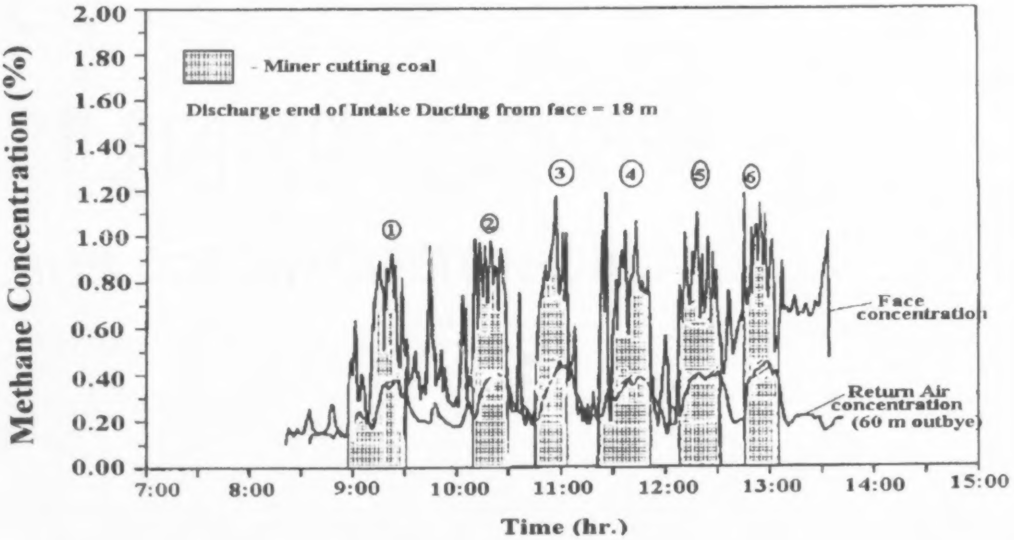


Fig. 4 - 10 Variation of Methane Concentration during Shift at Heading #4

(June 25, 1991)

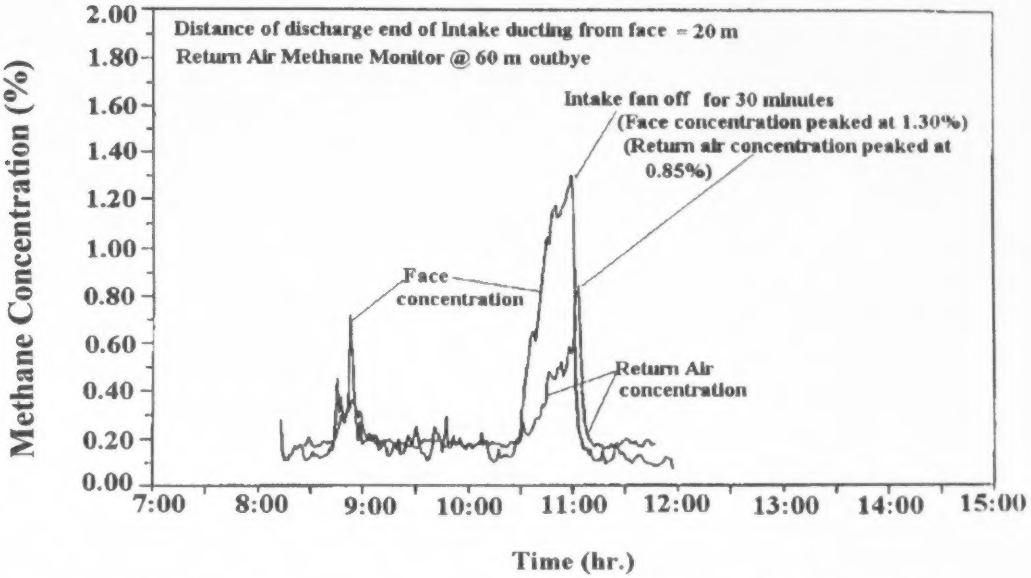


Fig. 4 - 11 Variation of Methane Concentration during Shift at Heading #5 (March 18, 1992)

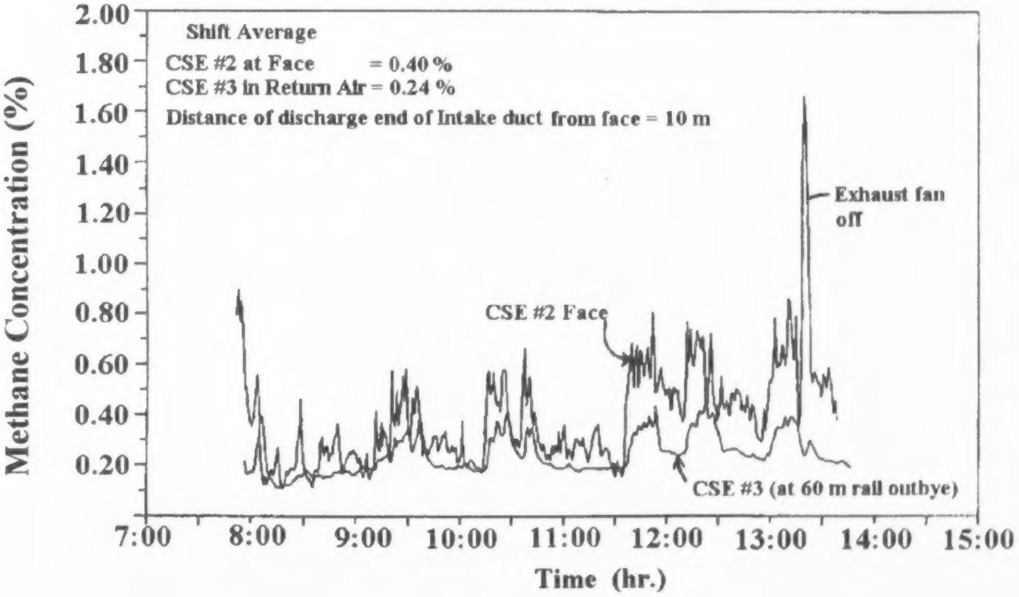


Fig. 4 - 12 Variation of Methane Concentration during Shift at Heading #4 (December 5, 1990)

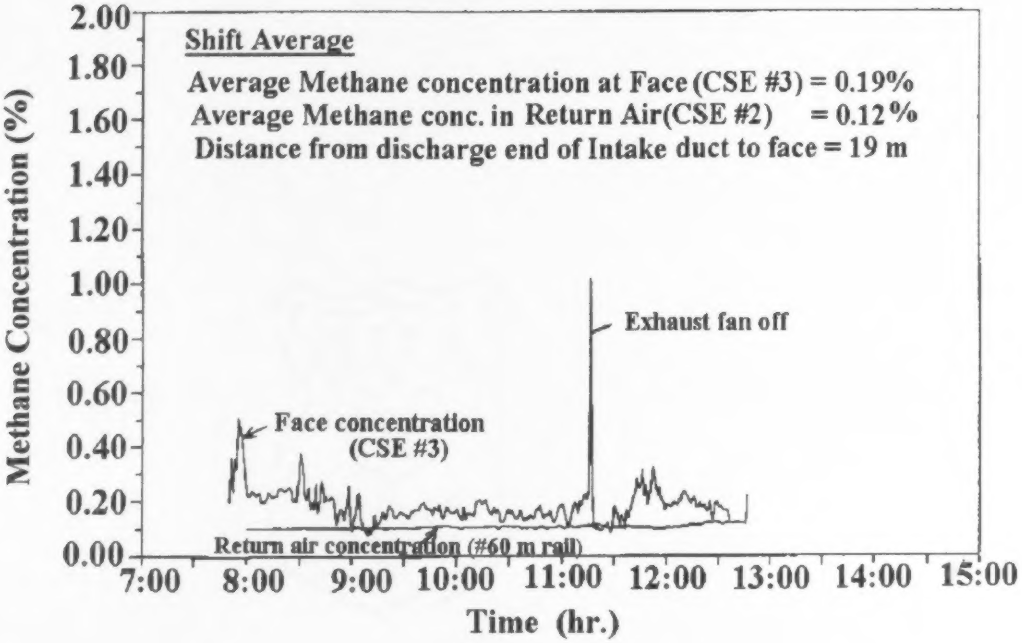


Fig. 4 - 13 Variation of Methane Concentration during Shift at Heading #4 (December 17, 1990)

face to about 60 m outbye) by the auxiliary ventilation systems in the headings under consideration. Thus the average concentration of methane in the return was virtually independent of the type of activity going on at the face and hence on the rate of emission of the methane within the control volume. However the methane concentration at the face is the determining factor since the electrical equipment at the face is not permitted to operate in an atmosphere having more than 1.0% or 1.25% concentration of methane by volume depending on the jurisdiction. Details on the efficiencies and effectiveness of the auxiliary ventilation systems are given in Sections 4.3.1 and 4.3.2.

A careful study of Figs. 4 - 3 to 4 - 13 and correlating them with the activities taking place at various times often reveal how the methane concentration in the heading can be easily affected by certain variables and changes that take place at the face during the shift. In Figs 4 - 5, 4 - 9 to 4 - 12, the continuous miner at the face made an average of four cuts during the shift while in Figs. 4 - 3, 4 - 7 and 4 - 13 just about one cut was made during the shift. Cutting periods (in one pass) ranged from 10 to 35 minutes. The average advance made per shift was 2 m in most headings studied.

Methane concentrations at the face were generally abnormally higher when there was a problem such as the sudden stoppage of the exhaust fan or the breaking of the forcing fan ducting, etc. (as depicted in Figs. 4 - 11 to 4 - 13). Cutting operations ceased immediately while normal methane concentration levels were restored (as evidenced by the drastic falls in methane concentrations in Figs. 4 - 11 to 4 - 13 immediately after the peaks). Other changes in the general trend in the methane concentrations, such as a gradual but steady rise in the methane concentration at the heading, can be easily discerned from these graphs. From Figs. 4 - 9 and 4 - 10, there is a gradually increasing trend in the level of methane concentration at the face with time which shows that the auxiliary ventilation systems were not always efficient in diluting the methane concentration to safe levels and effectively removing it from the face. As a result, in Fig. 4 - 9 (Heading #4) the average methane concentration at the face gradually rose from 0.40% at the beginning of cutting (at 8:00 am) to around 1.1% at 2:00 p.m. This represents an average rate of 0.14% per hour rise in the methane concentration at the face inspite of the existence of the auxiliary ventilation system. Fig. 4 - 10, which shows the methane concentrations recorded at the same heading about 6 months later, depicts the same gradually rising trend in methane concentration at the face as in Fig. 4 - 9. This was either due to the fact that the distance from the discharge end of the intake ducting to the face was gradually increasing as cutting of coal progressed or slightly increased emission rates from the new coal face exposed by cutting. However, it is clear that there was an inherent problem with the efficiency and effectiveness of the auxiliary ventilation system at the heading over the period as the ventilation system was not able to stabilize the methane concentration between cutting periods. In Fig. 4 - 9 the distance of the discharge end of the intake ducting from the face averaged 12 m while that in Fig. 4 - 10 was 18 m. This was probably one of the causes of the rising methane concentration at the face as most of the fresh air discharged from the intake ducting did not reach the face to dilute and clear the methane emitted during cutting.

Sudden and abnormal peaks or increasing trends in the methane concentration during the shift are often pointers to a problem with the auxiliary ventilation system such as stoppage of the intake air (the forcing fan as in Fig. 4 - 11) or of the exhaust fan (Figs. 4 - 12 and 4 - 13). It is also noteworthy that the average concentrations of methane as registered by both monitors at the face and in the return air were usually less than 0.4% when the duct distance to the face was less than 15 m (Figs. 4 - 3 to 4 - 8) whereas in headings where the discharge end of the intake ducting was greater than 15 m, the average concentrations of methane during the shift generally exceeded 0.5% (particularly at the face) as evident in Figs. 4 - 9 to 4 - 13. This situation was often made worse when there was a problem with either component of the overlap system. Further analysis of the data, as was done in this study and discussed in depth in the next sections, often aid in determining the critical elements of the system and in assessing the overall performance parameters of the auxiliary systems. These observations can assist the Mine Ventilation Engineer take the required corrective steps to ensure a better air supply and distribution system in the heading for contaminant (methane) dispersion.

4.2.2 Determination of Dilution Requirements

In order to determine the dilution requirements in any mine opening to effectively and safely dilute the concentration of any contaminant to statutory levels, it is necessary to have some knowledge of the rate of emission of the contaminant into the opening (room), the volume of the room, the nature, composition and concentrations of the mixtures of gases in the room.

In addition, it is necessary to know the explosibility of the mixture of gases in the opening. Fig. 4 - 14 (*commonly referred to as the Coward triangle for methane gas*) is the relation between the composition and explosibility of Methane-Air mixtures [33]. Knowledge of whether a particular mixture of gases is explosive or not enables the determination of not only the dilution requirements but also how to effectively and safely dilute the concentrations to safe levels.

The ultimate objective of any ventilation system is to maintain the concentration of oxygen in all workings above the minimum statutory requirements of 19.5%, to keep the oxygen concentration in the mixture as close as possible to point A (Fig. 4 - 14) and never to allow the concentrations of the gases in the mixture to fall within the explosive region defined by triangle BCE.

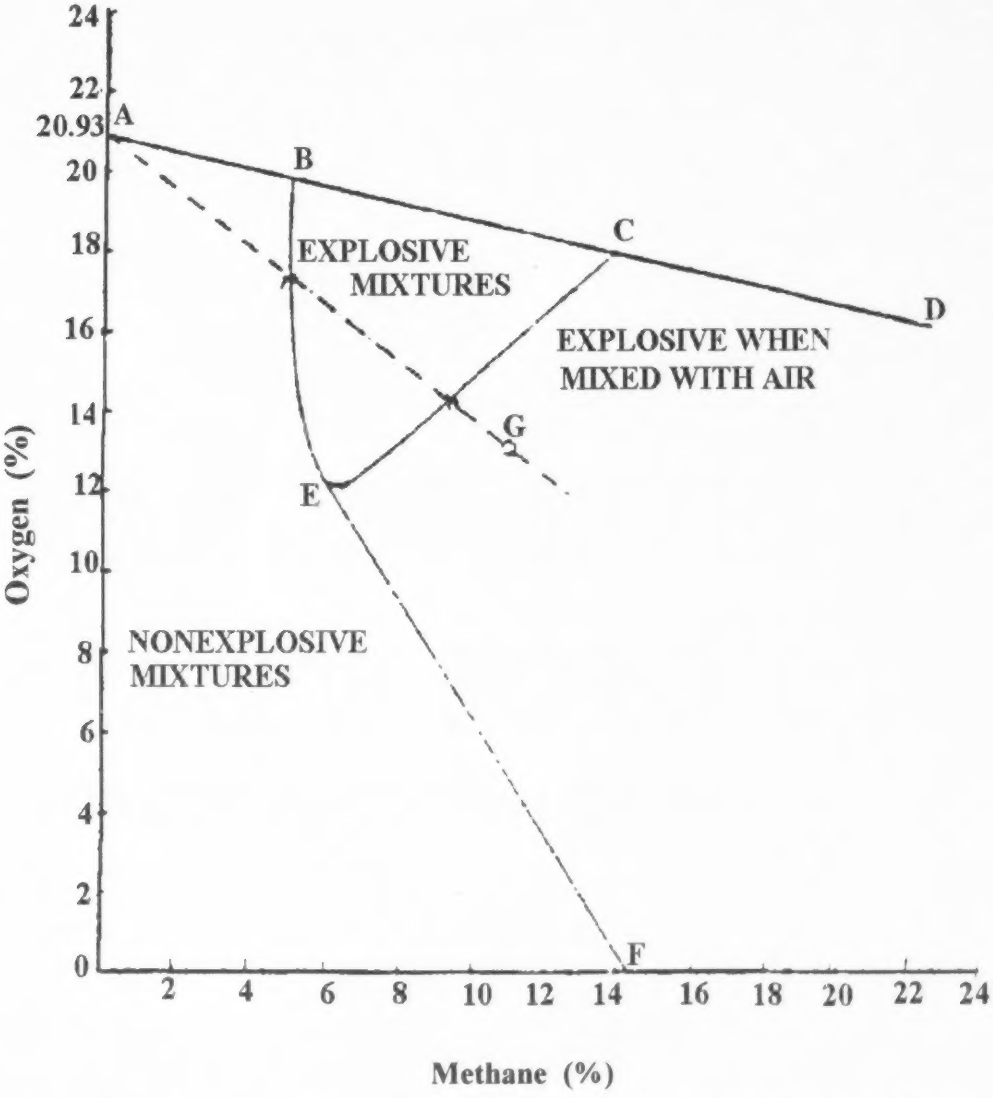


Fig. 4 - 14 Relation Between the Composition and Explosibility of Mixtures of Methane and Air

Also, as it would be impossible to dilute any mixture of gases from any point to the right of the zone DCEF (such as point G) without the concentration of the mixture passing through the explosive zone BCE, special dilution techniques and methods (*which are beyond the scope of this work*) are required to safely deal with such atmospheres when detected.

As most of the auxiliary ventilation systems studied in this work were the overlap systems (predominantly the primary forcing system with secondary exhaust overlap), most of the mathematical relations developed in this section refer to overlap systems with a main forcing fan and a secondary exhaust overlap. As the secondary exhaust overlap was usually mounted on the heading machine, the intake end of the secondary exhaust fan was constantly within 1 m from the face when the machine is cutting coal. The secondary exhaust overlap fan was only switched on when the heading machine was working. However, when required, these equations may easily be modified to apply to the other auxiliary ventilation methods.

The efficiency of any auxiliary ventilation system may be calculated from the following relation:

$$\text{Efficiency of Forcing System } (E_f) = \frac{\text{Air quantity discharged at duct end}}{\text{Quantity through primary auxiliary fan}} \times 100\%$$

$$E_f = \frac{Q_i}{Q_f} \times 100\% \qquad (4 - 1)$$

From Fig. 4 -1,

$$Q_f = Q_i + Q_l \qquad (4 - 2)$$

Equation (4 -1) often takes the form:

$$E_f = \frac{Q_i}{Q_i + Q_l} \times 100\% \qquad (4 -3)$$

where Q_f = Total quantity of air through the primary auxiliary fan at nearest through cross-cut, m^3/s

Q_i = Quantity of fresh air discharged at the end of the main forcing ducting, m^3/s

Q_l = Leakage air quantity through main forcing ducting, m^3/s.

When Q_l is very small compared to Q_i, as in a carefully installed line of new ducting, the efficiency of the forcing system approaches 100% {Equation (4 - 3)}.

However, as the overlap system is a hybrid of the forcing and exhausting systems, it is necessary to assess the overall efficiency of the overlap system. Equation (4 - 4) is the mathematical relation for the Overall Efficiency (E_o) of an overlap auxiliary ventilation system:

Overall Efficiency of Auxiliary System (E_o) =

$$\frac{\text{Quantity reaching the face}}{\text{Quantity through the primary auxiliary fan}} \times 100\%$$

$$E_o = \frac{Q_e}{Q_f} \times 100\% \qquad (4 - 4)$$

where Q_e = Quantity of intake air reaching the face of the working, m^3/s

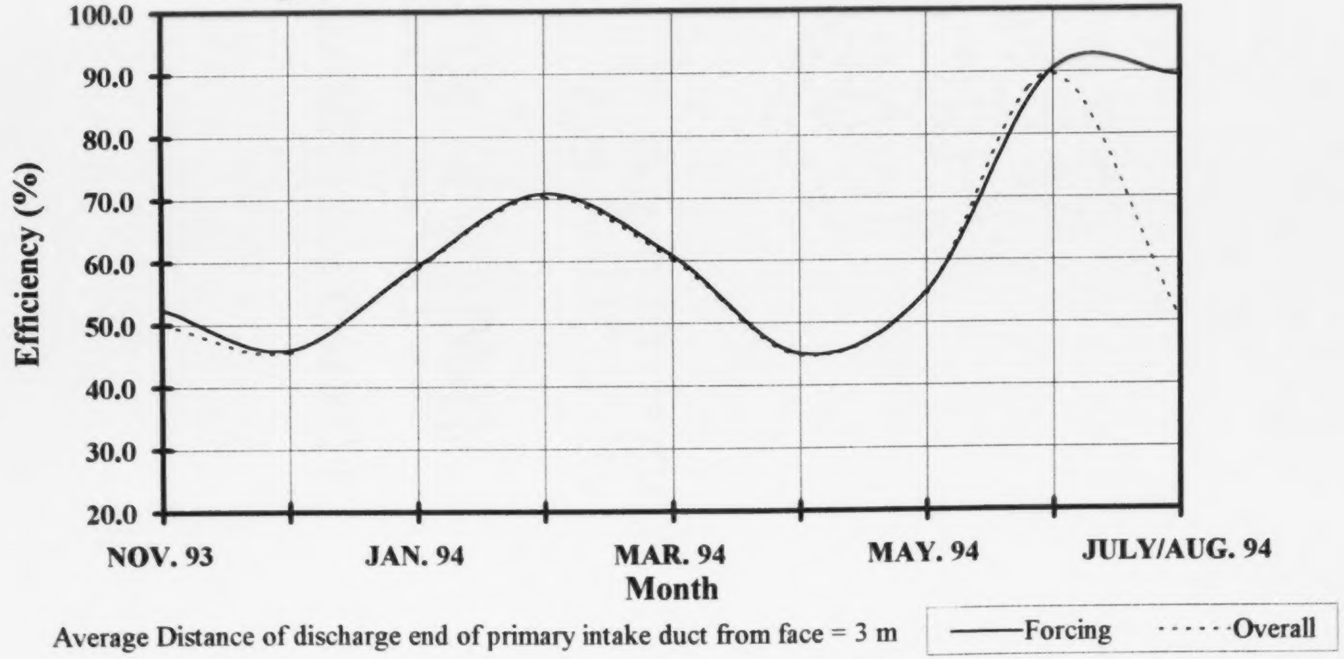
One constraint imposed by law on the amount of fresh air that can be drawn by the auxiliary ventilation system is that the intake quantity (Q_f) must not exceed 40% of the total main ventilating air quantity to the fan (Q_{t_1}) at the last through cross-cut [21]. {i. e. $Q_f \le 0.4 \times Q_{t_1}$} (See Fig. 4 -1).

The foregoing equations were employed in calculating the efficiencies of the auxiliary ventilation systems in development headings for the period November 1993 to August 1994. The results are summarized in Appendices B - 1 to B - 11. Figs. 4 - 15 to 4 - 25 are plots of the efficiencies of the auxiliary ventilation systems as a function of time at the development headings studied.

The mean efficiencies of the forcing systems varied from a low of 48.87% (in Heading #11) to 96.81% in Heading #20. The mean efficiencies of the overall auxiliary ventilation systems ranged from 6.04% in Heading #20 to 58.18% in Heading #1. It is significant to note that while Heading #20 had the best forcing system (96.81%) it also had the least efficient overall system (6.04%) due primarily to excessive distance of the discharge end of the intake ducting from the face.

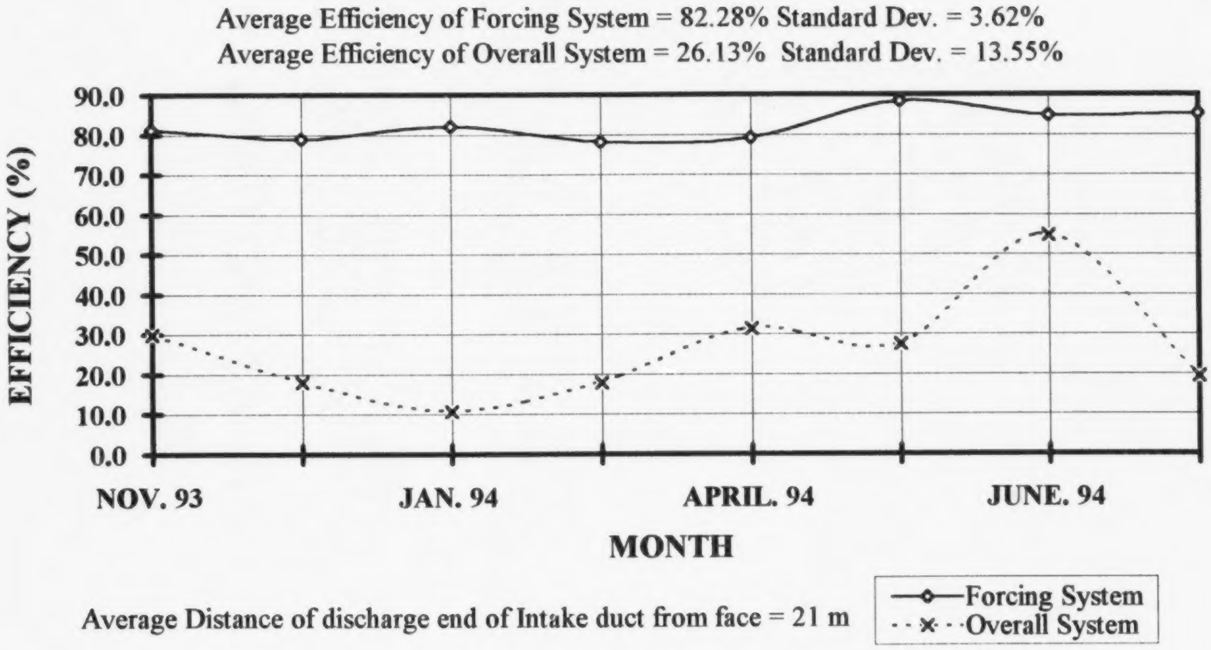
Fig. 4 - 15 Variation of Efficiencies of Auxiliary Ventilation System with Time at Heading #1

Average Efficiency of Forcing System = 63.22% Standard Dev. = 17.02%
Average Efficiency of Overall System = 58.16% Standard Dev. = 14.24%



Average Distance of discharge end of primary intake duct from face = 3 m

Fig. 4 - 16 Variation of Efficiencies of Auxiliary Ventilation System with Time at Heading #2



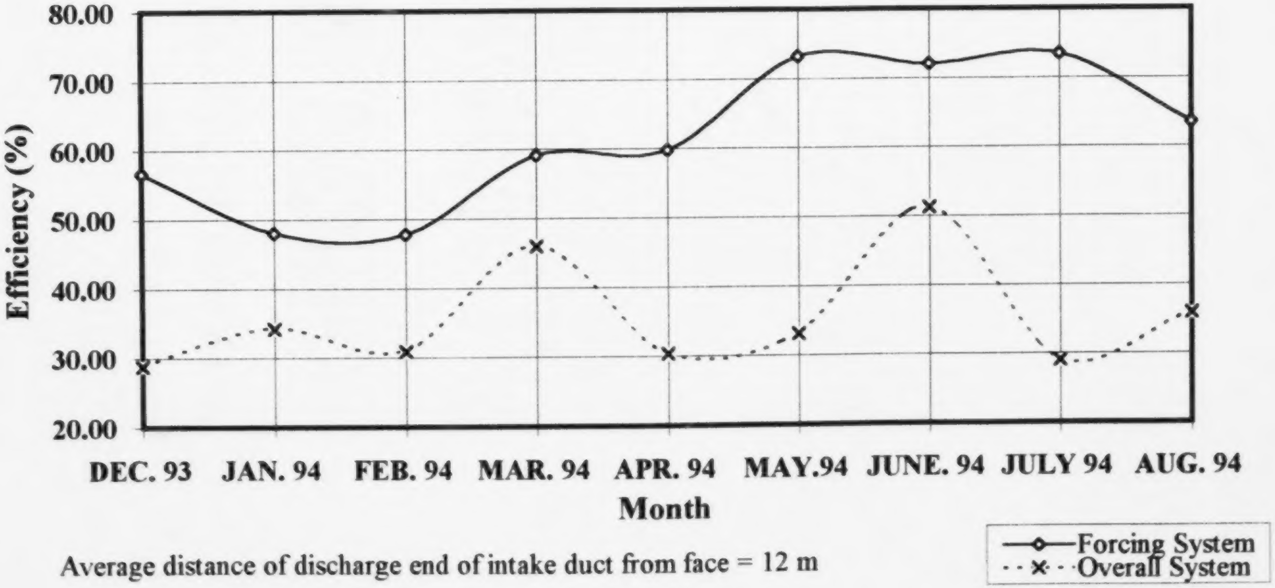
Average Efficiency of Forcing System = 82.28% Standard Dev. = 3.62%
Average Efficiency of Overall System = 26.13% Standard Dev. = 13.55%

Average Distance of discharge end of Intake duct from face = 21 m

Fig. 4 - 17 Variation of Efficiencies of Auxiliary Ventilation System with Time at Heading #8

Average Efficiency of Forcing System = 61.50% Standard Deviation = 10.00%

Average Efficiency of Overall System = 35.46% Standard Deviation = 7.91%

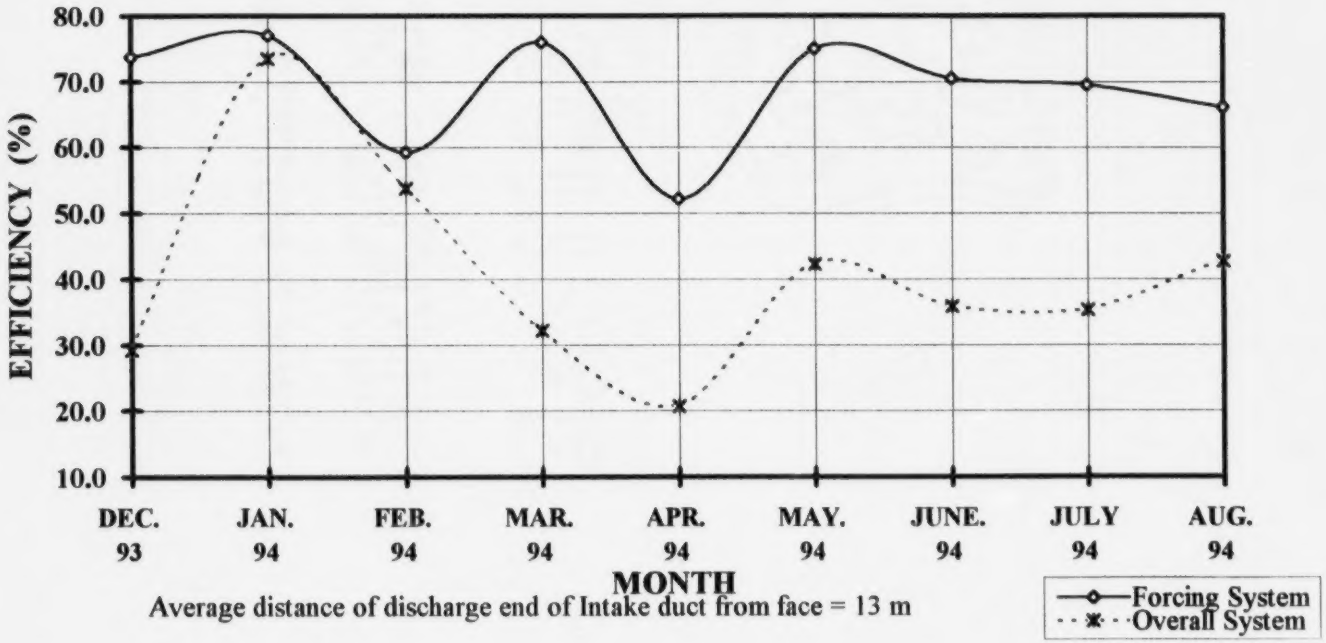


Average distance of discharge end of intake duct from face = 12 m

Fig. 4 - 18 Variation of Efficiencies of Auxiliary Ventilation System with Time at Heading #9

Average Efficiency of Forcing System = 68.81% Standard Dev. = 8.37%

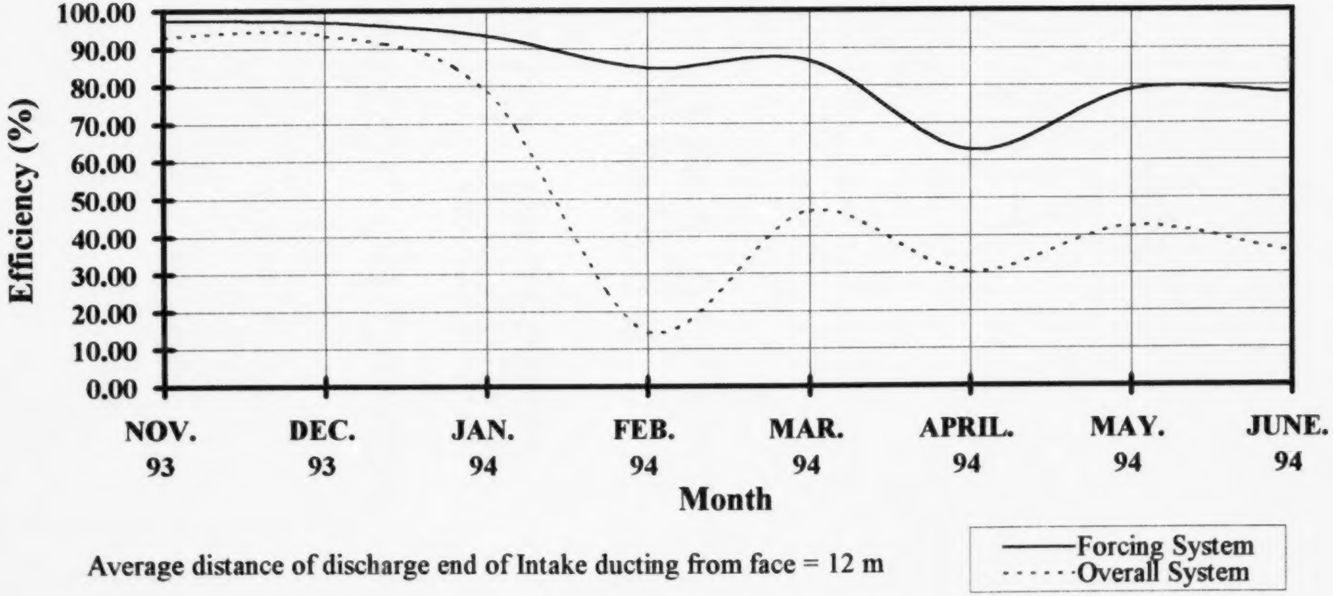
Average Efficiency of Overall System = 40.57% Standard Dev. = 15.46%



Average distance of discharge end of Intake duct from face = 13 m

Fig. 4 - 19 Variation of Efficiencies of Auxiliary Ventilation System with Time at Heading #10

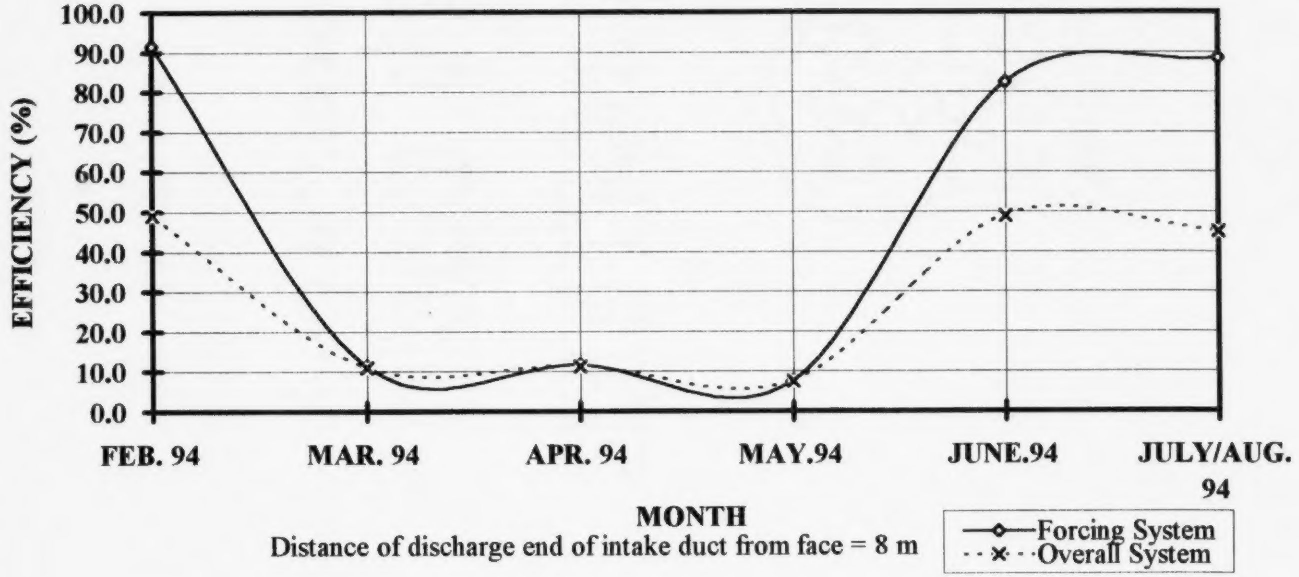
Average Efficiency of Forcing System = 84.84% Standard Dev. = 11.66%
Average Efficiency of Overall System = 54.16% Standard Dev. = 30.13%



Average distance of discharge end of Intake ducting from face = 12 m

Fig. 4 - 20 Variation of Efficiencies Auxiliary Ventilation System with Time at Heading #11

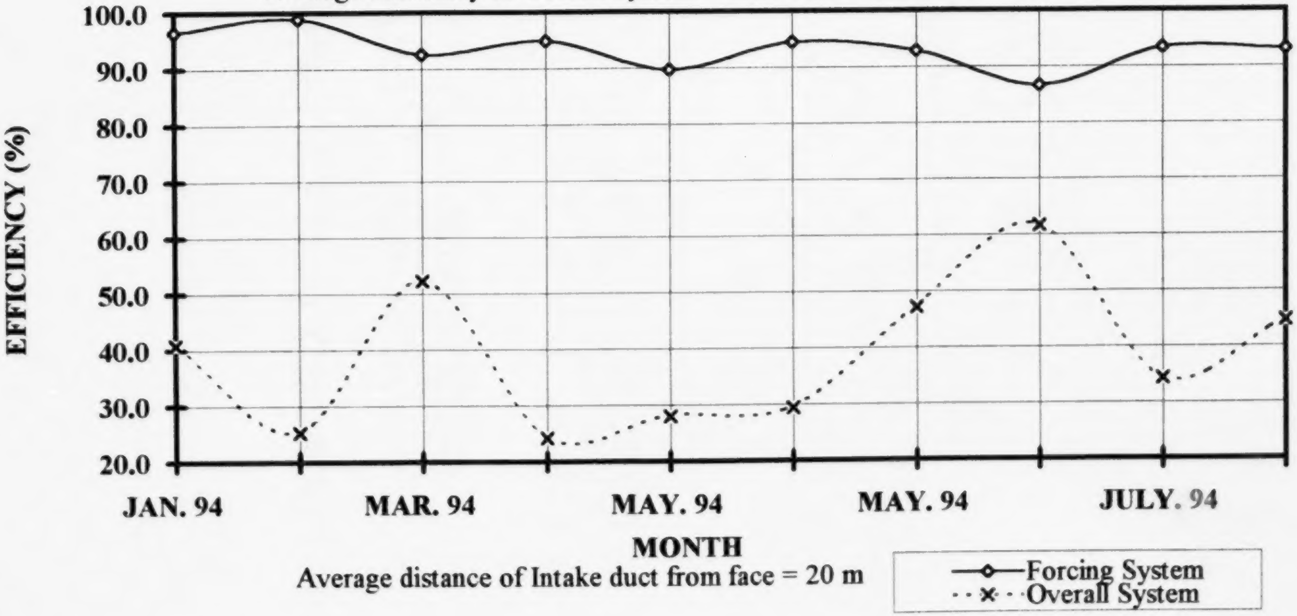
Average Efficiency of Forcing System = 48.87% Standard Dev. = 42.47%
Average Efficiency of Overall System = 28.71% Standard Dev. = 20.77%



Distance of discharge end of intake duct from face = 8 m

Fig. 4 - 21 Variation of Efficiencies of Auxiliary Ventilation System with Time at Heading # 13

Average Efficiency of Forcing System = 94.51% Standard Dev. =3.14%
Average Efficiency of Overall System = 33.30% Standard Dev. = 11.01%

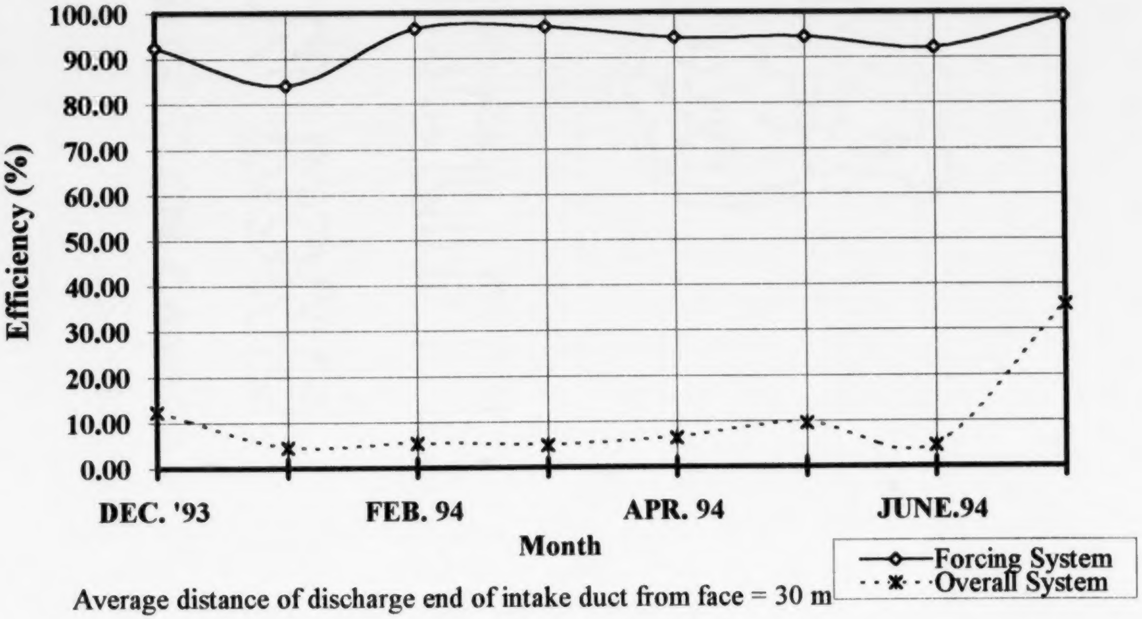


Average distance of Intake duct from face = 20 m

Fig. 4 - 22 Variation of Efficiencies of Auxiliary Ventilation System with Time at Heading #19

Average Efficiency of Forcing System = 93.81% Standard Deviation =4.57%

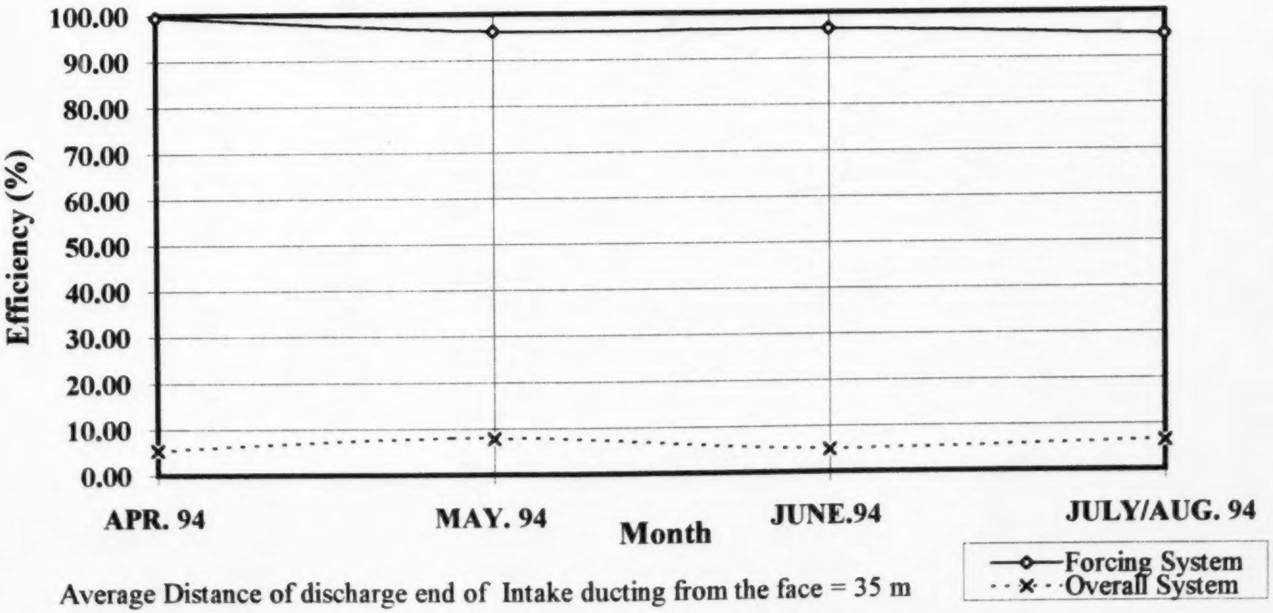
Average Efficiency of Overlap System = 10.37% Standard Deviation = 10.54%



Average distance of discharge end of intake duct from face = 30 m

Fig. 4 - 23 Variation of Efficiencies of Auxiliary Ventilation System with Time at Heading #20

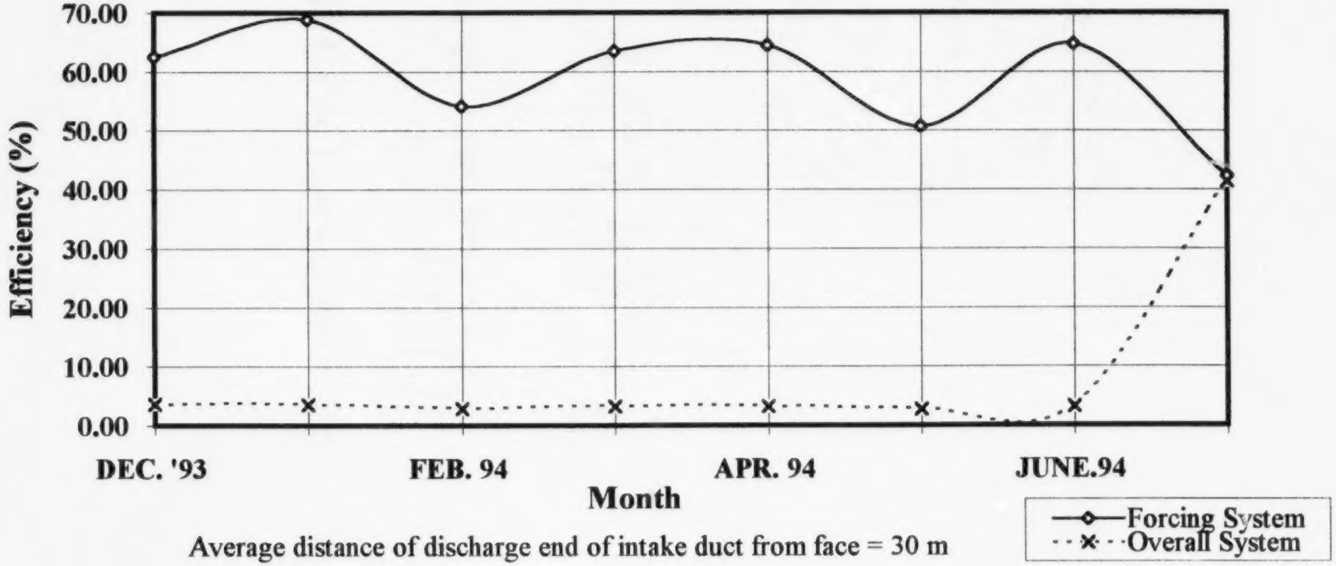
Average Efficiency of Forcing System = 96.81% Standard Deviation = 1.89%
Average Efficiency of Overall System = 6.04% Standard Deviation = 1.27%



Average Distance of discharge end of Intake ducting from the face = 35 m

Fig. 4 - 24 Variation of Efficiencies of Auxiliary Ventilation System with Time at Heading #22

Average Efficiency of Forcing System = 58.91% Standard Deviation = 8.95%
Average Efficiency of Overall System = = 7.97% Standard Deviation = 13.49%

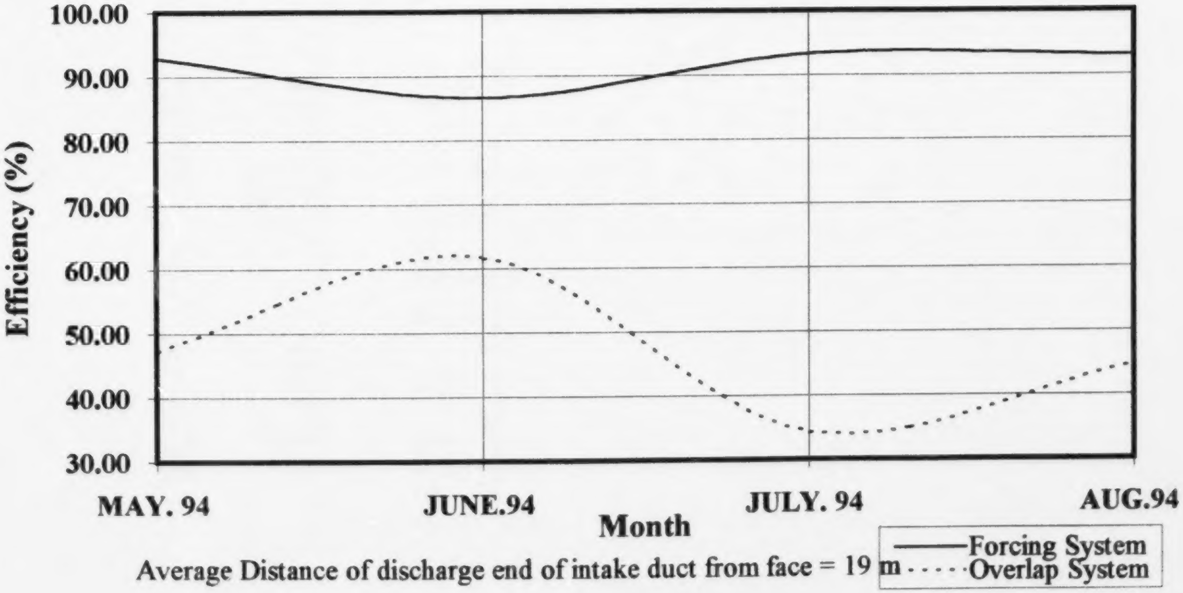


Average distance of discharge end of intake duct from face = 30 m

Fig. 4 - 25 Variation of Efficiencies of Auxiliary Ventilation System with Time at Heading #14

Average Efficiency of Forcing System = 91.46% Standard Deviation = 3.25%

Average Efficiency of Overlap System = 46.89% Standard Deviation = 11.26%



Average Distance of discharge end of intake duct from face = 19 m

In Fig. 4 - 15, there was a very good correlation between the efficiencies of the forcing and overall systems over the period of evaluation as they were virtually the same. This meant that all the fresh air supplied by the forcing system reached the face resulting in the values of the overall system efficiency being almost the same as those of the forcing system. The efficiencies of the forcing and overall systems improved from about 52% in November 1993 to 71% in February 1994. The efficiencies of the auxiliary ventilation system in the heading however deteriorated over the next two months to 45% in April 1994 but took an upward trend in the succeeding months.

The excellent agreement that existed between the efficiencies of the forcing and overall systems from December 1993 to May 1994 in Fig. 4 - 15 was broken after June 1994. From Appendix B - 1, the factors that accounted for these variations in the efficiencies of the auxiliary system can be discerned. Between November 1993 and January 1994, a 44.76 kW (60 HP) Engart fan was being employed with a new 1070 mm (42 in.) diameter 590 m long ventilation ducting. The distance from the discharge end of the intake ducting to the face was reduced from 5 m in November 1993 to 1 m between December 1993 and March 1994. This meant that all the intake air reached the face and resulted in the increases in both the forcing and overall efficiencies over the period.

However, between February 1994 and the end of April 1994, the main auxiliary forcing fan capacity was reduced to 22.38 kW (30 HP). As a result the quantity of air through the fan dropped to about 30% of the initial quantity supplied by the previous fan. While the exact fan characteristics cannot be discerned from the data provided, it is reasonable to assume that under the same operating conditions of the system, the change in the capacity of the fan may have been largely responsible for the drops in the efficiencies of the forcing and overlap systems during the period. Increased amounts of leakage through the ventilation ducting as the ductings aged may have accounted for further drops in the efficiencies of the systems in the heading over the period.

In May 1994, the capacity of the main auxiliary fan was increased to 55.95 kW (75 HP) and this led to an improvement in the efficiencies of both the forcing and the overall systems. The overlap system was slightly more efficient than the forcing system between

May and June 1994. While the efficiency of the forcing system was improving between May and July 1994, the overall system efficiency began deteriorating after June 1994 due to the fact that the distance from the discharge end of the intake duct (which averaged 1 m over the previous months) had increased to 12 m and very little fresh air reached the face.

Wide differences between the efficiencies of the forcing and overall systems, as evidenced in Figs. 4 - 16 to 4 - 19, 4 - 21 to 4 - 25, were mainly attributable to the long distances from the discharge end of the intake duct (which ranged from 12 to 35 m) to the face. The worst scenarios were in Figs. 4 - 21 to 4 - 24 where distances from the discharge end of the intake ductings to the face exceeded 20 m. While the forcing efficiencies in those headings were generally high (>55%), the overall system efficiencies were low (<15%). This meant that the auxiliary ventilation systems in the headings failed to make use of the merits of both the main forcing system and that of the secondary exhausting system as each system was virtually operating in isolation. Much of the fresh air supplied by the main auxiliary forcing system did not reach the face (and the intake of the exhaust fan) to effectively clear the contaminants. In Figs. 4 - 23 and 4 - 24, while the forcing system efficiencies were greater than 58%, the overall system efficiencies were negligible (< 7%).

Interestingly, while the duct distance from the face in Heading #11 (Fig. 4 - 20) was about 8 m over the 6 months' period, the efficiencies of both the forcing and overall systems were generally low (< 15%) between March and May 1994. A close examination of the data in Appendix B - 5 indicates that this was apparently due to the change in the diameter of the ducting from 1070 mm to 300 mm as all the other variables that normally affect the efficiency of an auxiliary ventilation system (*such as fan capacity, length of ducting, etc.*), remained the same over the period.

Significantly, the 22.38 kW fan that was employed in the Heading #11 (Fig. 4 - 20) with a 1070 mm diameter ventilation ducting in June 1994 had almost the same forcing and overall efficiencies as the 55.95 kW fan that was employed in July/August 1994 using the same diameter ducting. This was presumably due to the increased resistance and possible leakages over the extra length of ducting (175 m) that was added after June 1994. Increased distances from the discharge end of the main forcing ducting to the face (>11 m) were principally responsible for the lower efficiencies of the overall system in Fig. 4 - 20 (compared to the forcing system) between June and July 1994.

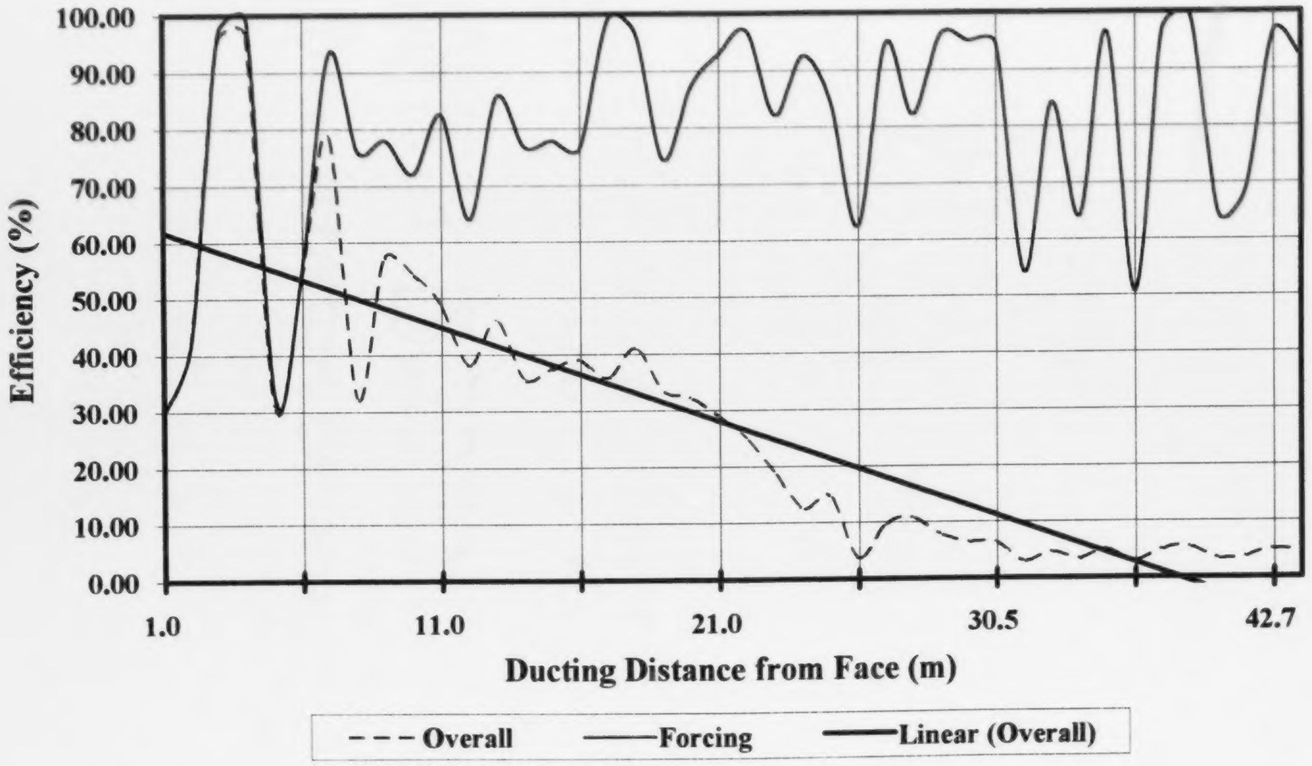
Fig. 4 - 26 shows the distance from the discharge end of the intake ducting to the face as function of the efficiencies of the forcing and overall systems from 76 measurements at different headings. While the forcing system efficiency is not affected by distance from the discharge end of the intake ducting to the face, the overall system efficiency is clearly (*as expected*) inversely proportional to the distance from the end of the ducting to the face. From the trendline, the overall system efficiency is found to be zero at about 40 m from the face. This means that in auxiliary ventilation systems where the distance from the end of the intake ducting to the face is in excess of 40 m, it is not likely that any fresh air will reach the face to dilute and disperse the contaminants. For distances not exceeding 10 m, the overall system efficiencies are above 45% while overall system efficiencies above 30% can only be achieved if the distance from the intake ducting to the face does not exceed 15 m. (See Fig. 4 - 26).

In brief, the foregoing analysis show how the efficiencies of the forcing and overall systems in an auxiliary ventilation system are largely affected by drivers of the system such as fan capacity, length, diameter and condition of the ventilation ducting, and especially the distance of the discharge end of the intake ducting from the face. While it is difficult to accurately assess all the system efficiencies from the limited data available, it is reasonable to say that distances from the discharge end of the intake ducting to the face not exceeding 10 m will ensure that at least 45% of the intake air reaches the face and that will ensure good to excellent methane dispersion, dilution and safe removal from the development headings.

4.3 Methane Liberation and Concentration Buildup Rates

As discussed in Chapter 2, the equilibrium that exists between free methane gas in the pore spaces and fissures and adsorbed gas on the surfaces of the same pores and

Fig. 4 - 26 Efficiency as a Function of Duct Distance from Face



fissures is disrupted when a mine opening is driven through the strata. The factors that determine the rate of methane emission into mine openings were detailed.

As it is impossible to prevent the emission of methane and other strata gases into mine openings, it is prudent to adopt ways of not only reducing the amount of methane gas emitted but also controlling the methane gas concentrations within safe levels. Methane drainage in advance of mining, sealing off mined out or very gassy sections and areas and dilution by the main or auxiliary ventilation systems are some of the common methods used to control the rate of methane emission into mine openings [4]. The latter is the most common method employed in coal mines when the methane emission rate is small to medium as it is more versatile, the least expensive and most effective of the three options [1]. The other two options become feasible (*economically*) when the methane emission rates are high (> 8 m^3/t) [4, 13]

Under steady state conditions where there is no compressibility in the system, the following constraints are applicable in the calculation of methane buildup rate in a control volume (G, m^3) within a coal mine roadway: $G > 0$; $C_{CH_4} \geq 0$.

Employing the law of conservation of mass, mathematical relations can be derived on the airflow through a region in a space which is defined as the control volume. The properties of the air are analyzed as it enters and leaves this space called the control volume.

The methane concentration is defined as the ratio of the rate of methane intake to that of the fresh air intake into the opening. Assuming instantaneous and thorough mixing of the gases, the concentration of methane under steady state conditions (*assuming that there is no methane in the normal intake air*) may be expressed mathematically as [34]:

$$C = \frac{\text{Methane make in heading}}{\text{Fresh Air Intake into heading}} \times 100\%$$

$$= \frac{Q_{CH_4}}{Q_i} \times 100\% \qquad (4\text{-}5)$$

where C = Methane concentration in the heading, percent

Q_{CH_4} = Quantity of methane emanating from the strata, m^3/s

Q_i = Quantity of intake air discharged from the end of the ventilation ducting, m^3/s

It is clear from equation (4 - 5) that the concentration of methane in any ventilated heading (or room) is governed by the methane emission rate and the rate of flow of fresh air into the heading (room). Large fresh air flow rates will normally result in low methane concentrations in the heading.

From the continuity equation, the mass flow rate of gases entering the control surface (Figs. 4 -1 and 4 - 27) must equal the mass flow rate that leaves the control surface. This is expressed as follows:

$$M_1 + M_2 = M_3 \qquad (4 - 6)$$

i.e.

$$\rho_1 A_1 V_1 + \rho_2 A_2 V_2 = \rho_3 A_3 V_3 \qquad (4 - 7)$$

where M_1 = Mass flow rate of the intake air, kg/s

M_2 = Mass flow rate of methane gas (from the strata), kg/s

M_3 = Mass flow rate of the return air, kg/s

A = Flow area measured normal to the direction of flow direction.

ρ_1, = density of the intake air, kg/m^3

ρ_2 = density of methane gas, kg/m^3

ρ_3 = density of the return air, kg/m^3

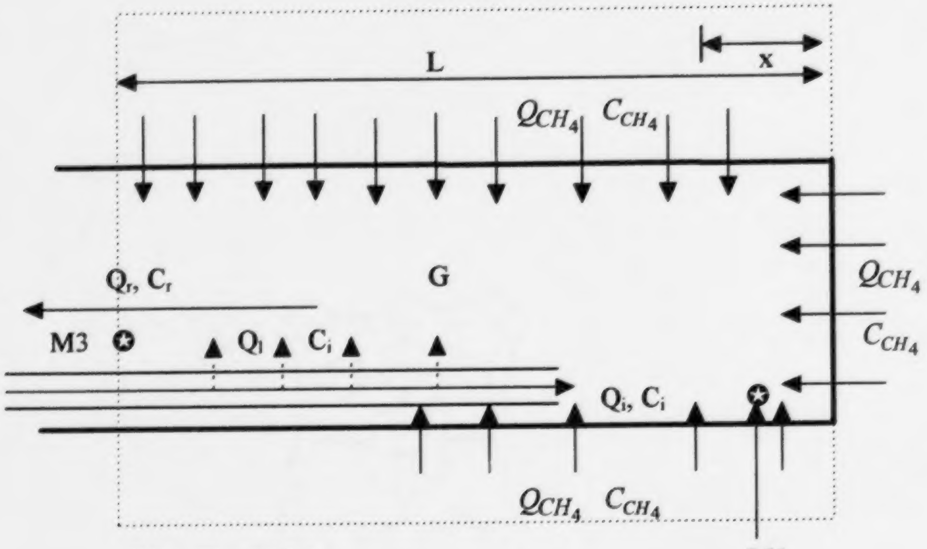
V_1, V_2, V_3 are the velocities of the intake air, methane gas and return air (m/s) respectively.

Applying these equations to the flow situation in Figs. 4 - 1, 4 - 27 and 4 - 28, assuming that either the density of the air is constant or the density changes are minimal, equation (4 - 7) may be written as:

$$\rho_1 (Q_i + Q_l) + \rho_2 Q_{CH_4} = \rho_3 Q_r \qquad (4 - 8)$$

where Q_l = Leakage quantity through main auxiliary forcing ducting, m^3/s

Since $Q_f = Q_i + Q_l$ {See equation (4 - 2)}


L
x
Q_{CH_4} C_{CH_4}
Q_r, C_r
G
Q_{CH_4}
C_{CH_4}
M3
Q_l C_i
Q_i, C_i
Q_{CH_4} C_{CH_4}
M1

(Not To Scale)

Fig. 4 - 27 Schematic of the Control Volume where Methane Emissions and Dilution with Intake Air Occur at the Face of a Heading.

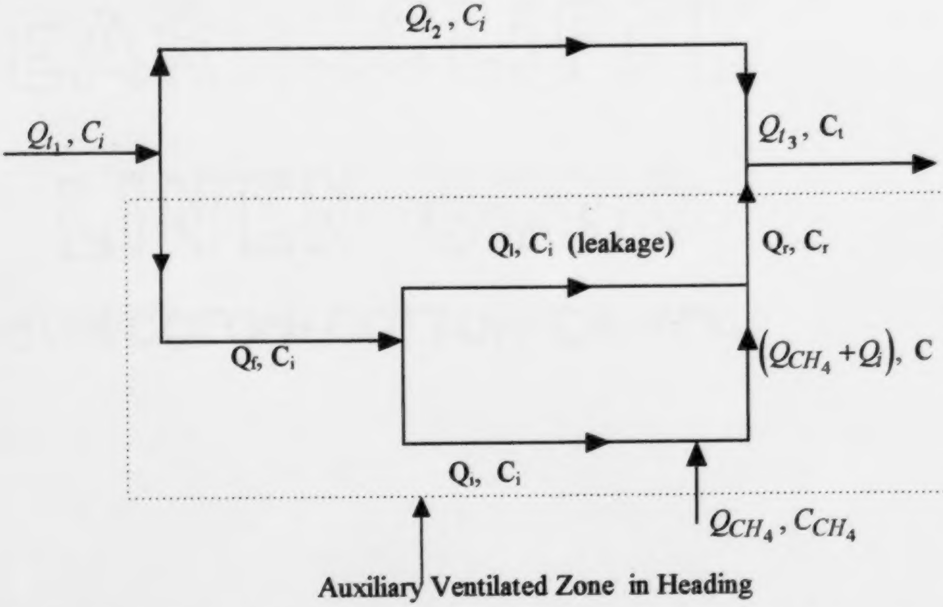

Q_{t_2}, C_i
Q_{t_1}, C_i
Q_{t_3}, C_t
Q_l, C_i (leakage)
Q_r, C_r
Q_f, C_i
$(Q_{CH_4} + Q_i)$, C
Q_i, C_i
Q_{CH_4}, C_{CH_4}
Auxiliary Ventilated Zone in Heading

Fig. 4 - 28 A Simplified Network Diagram of Flow System at the Face of the Heading

equation (4 - 8) simplifies to:

$$\rho_1 Q_f + \rho_2 Q_{CH_4} = \rho_3 Q_r \qquad (4 - 9)$$

The following equations may also be written:

$$Q_r = Q_i + Q_{CH_4} + Q_l \qquad (4 - 10)$$

$$C_r Q_r = C_i Q_i + Q_l C_i + C_{CH_4} Q_{CH_4} \qquad (4 - 11)$$

$$Q_{t_1} = Q_f + Q_{t_2} \qquad (4 - 12)$$

$$Q_{t_3} = Q_{t_2} + Q_r \qquad (4 - 13)$$

where Q_{t_1} = Total intake air quantity in main ventilation airstream, m^3/s

Q_{t_2} = Quantity of intake air in last through cross-cut which does not pass through the heading, m^3/s

Q_{t_3} = Total quantity of air in immediate region on the downstream side of the last through cross-cut, m^3/s

Q_i = Quantity of air discharged at end of ducting, m^3/s

Q_f = Air quantity through fan, m^3/s

Q_l = Leakage quantity through the main forcing ducting, m^3/s

Q_r = Return air quantity in the heading, m^3/s

C_{CH_4} = Concentration of methane emanating from strata

C_i = Methane concentration in normal intake air.

C_r = Methane concentration in return air, %.

(C_{CH_4}, C_i and C_r are expressed on a fractional basis).

From Equations (4 - 6) to (4 - 13) the following relations are obtained:

$$C_r\,(\%) = \left[\frac{Q_f\,C_i + C_{CH_4}Q_{CH_4}}{Q_f + Q_{CH_4}}\right] \times 100\% \qquad (4-14)$$

$$Q_{CH_4} = \frac{Q_f}{100}\left(\frac{C_r - C_i}{C_{CH_4} - C_r}\right) \qquad (4-15)$$

There are several sources of methane emissions in the mine opening. The main ones are from the walls of the airway (this includes the working face and the ribs and side walls of the opening), and from the gob areas (*when the airway is close to worked out areas*). The mathematical model of the dynamics of methane emission from the walls of an airway is based upon the mass conservation law, and the dilution requirements in a given volume, G (m^3), at the face of Fig. 4 - 1 (under unsteady state conditions) can be expressed by the following ordinary differential equation [34]:

$$\frac{G\,dC}{dt} = Q_i C_i + Q_l C_i + Q_{CH_4} C_{CH_4} - \left[Q_{CH_4} + Q_i + Q_l\right]C$$

$$= Q_f\,C_i + Q_{CH_4}C_{CH_4} - \left[Q_f + Q_{CH_4}\right]C \qquad (4-16)$$

where G = Volume of mine opening (the control volume), m^3

= $L \times A$

L = Distance from face to return air methane monitor position, m

A = Cross-sectional area of the roadway, m^2

Q_f = Air quantity through main auxiliary forcing fan, m^3/s

C = Concentration of methane within the zone expressed on a fractional basis

dt = change in time, s.

dC = rate of change in methane concentration (C) at time t.

C_{CH_4} = methane concentration at any time (expressed as fraction)

Q_i, Q_{CH_4} and Q_l are as defined previously.

Rearranging equation (4 - 16) and integrating with respect to elapsed time (t), the following relationship is obtained:

$$C\,e^{\beta_3 t} = \left(\frac{\beta_1 C_i + \beta_2 C_{CH_4}}{\beta_3}\right) \times e^{\beta_3 t} + I \qquad (4 - 17)$$

where I = a constant of integration

$$\beta_1 = \frac{Q_f}{G};\ \beta_2 = \frac{Q_{CH_4}}{G} \text{ and } \beta_3 = \frac{Q_f + Q_{CH_4}}{G}$$

Applying the initial conditions: at $t_o = 0$, $C = C_o$, then

$$I = -\frac{1}{\beta_3}\ln\left(\beta_1 C_i + \beta_2 C_{CH_4} - \beta_3 C_o\right)$$ and equation (4 - 17) simplifies to:

$$C = \left\{\frac{Q_f C_i + Q_{CH_4} C_{CH_4}}{Q_f + Q_{CH_4}}\right\} + \left[C_o - \left(\frac{Q_f C_i + Q_{CH_4} C_{CH_4}}{Q_f + Q_{CH_4}}\right)\right] \times e^{-\left[\left(\frac{Q_f + Q_{CH_4}}{G}\right)t\right]} \qquad (4 - 18)$$

from which t can be derived as:

$$t = \left(\frac{G}{Q_f + Q_{CH_4}}\right)\ln\left[\frac{Q_f C_i + Q_{CH_4} C_{CH_4} - C_o\left(Q_f + Q_{CH_4}\right)}{Q_f C_i + Q_{CH_4} C_{CH_4} - C\left(Q_f + Q_{CH_4}\right)}\right] \qquad (4 - 19)$$

where t = time elapsed (time for dilution), s

C_o = methane concentration at time t = 0 (expressed as fraction)

In the unsteady state, knowing the ventilating quantity, the gas inflow rate, the initial and final gas concentrations, the time for dilution can be determined from the following equation [1]:

$$t = \frac{G}{Q_f}\ln\left(\frac{Q_{CH_4} - Q_f C_o}{Q_{CH_4} - Q_f C}\right) \qquad (4 - 20)$$

Where the leakage quantity (Q_l) through the ventilation ductings is very small *(as in well-installed ventilation ductings)* compared to the inflow rate of fresh air (Q_i) into the heading (i. e. $Q_l << Q_i$,), $Q_i \cong Q_f$ {refer to equation (4 - 2)}. Thus equation (4 - 20) often assumes the familiar form:

$$t = \frac{G}{Q_i} \ln\left(\frac{Q_{CH_4} - Q_i C_o}{Q_{CH_4} - Q_i C}\right) \qquad (4 - 21)$$

4.3.1 Rate of Purging

To determine the rate of decrease in the concentration of a contaminant (*in this case methane gas*) over a period of time by some fixed rate of ventilation, {assuming that the methane emission rate is very small compared to the volume flow rate of the intake air into the heading ($Q_{CH_4} << Q_i$)} equation (4 - 21) is often further simplified to [35]:

$$t = \frac{G}{Q_i} \ln\left(\frac{C_o}{C}\right) \qquad (4 - 22)$$

In the steady state condition, a prevalent condition in dilution [1], where thorough mixing of the gases is assumed and time for dilution is very long, (t → ∞), equation (4 - 18) simplifies to:

$$Q_i = Q_{CH_4}\left(\frac{C_{CH_4} - C}{C - C_i}\right) \qquad (4 - 23)$$

As the concentration of methane emanating from the strata (C_{CH_4}) is assumed to be pure (100%), equation (4 - 23) becomes [36]:

$$Q_i = Q_{CH_4}\left(\frac{1 - C}{C - C_i}\right) \qquad (4 - 24)$$

where $Q_i, Q_{CH_4}, C_{CH_4}, C, C_i$ are as previously defined.

Equations (4 - 6) to (4 - 24) were employed in calculating the methane emission rates in the headings studied. The results are given in Appendices C, D and E. The concentration of methane emanating from strata (C_{CH_4}) was assumed to be 100% in the calculations. The methane concentration in the normal intake air (C_i), was taken as 0.15% for Mine No. 3 and 0.10% for Mine No. 8 (being the averages of the methane concentrations in the general body of mine air calculated from previous ventilation surveys).

Figs. 4 - 29 to 4 -31 are graphs of methane emission rates as a function of time at Heading Nos. 9, 10 and 11 respectively. In Fig. 4 - 30, there are some zones of negative emission rates. These may be attributed to either the fact that some of the methane was adsorbed or absorbed by the surrounding walls or that due to the movements and relative positions of the heading machine, men and other equipment at the face, some of the fresh air was deflected during times of the shift directly on to the methane monitor at the face resulting in it recording far lower methane concentrations than outbye. Characteristically, these graphs correlate very well in time with those of Figures 4 - 3 to 4 - 8. The average methane emission rates from Headings 3, 5, 8, 9, 10 and 11 (discounting the negative values) were calculated to be 0.0072, 0.0293, 0.0338, 0.00510, 0.00170 and 0.00150 m^3/s respectively (Figs. 4 - 29 to 4 - 31 and Appendix F - 1). These values are far lower than the average emission rates of the top 25 coal mines in the U.S. (See Table 2 - 6) but about the same as the emission rates of the civil engineering tunnels spread throughout five states in the U. S. as stated on page 32.

4.3.2 Design of Auxiliary Ventilation Systems

As the response times of most methane measuring, monitoring and flammable gas warning devices and instruments range from 10 to 15 seconds (when the shield is clean) and up to 25 seconds or more (when the shield is either dirty or wet) [37], after which the face equipment is de-energized almost instantaneously, it means that these instruments will only be able to display a reading of the methane concentration in the ambient air or give an audible warning sign and de-energize any electrical equipment at the face when a pre-set concentration of methane (such as the lower legislative limit of methane) has been exceeded for about one-half minute. It is highly probable that a higher methane concentration level could occur before any warning sign is given by the monitor. As it is safer to err on the generous side, it is necessary to design the auxiliary ventilation system in any heading such that the methane concentrations can be purged to safe levels in about one minute.

Fig. 4 - 29 Relationship between Methane Emission Rate and Time of Shift at Heading #9

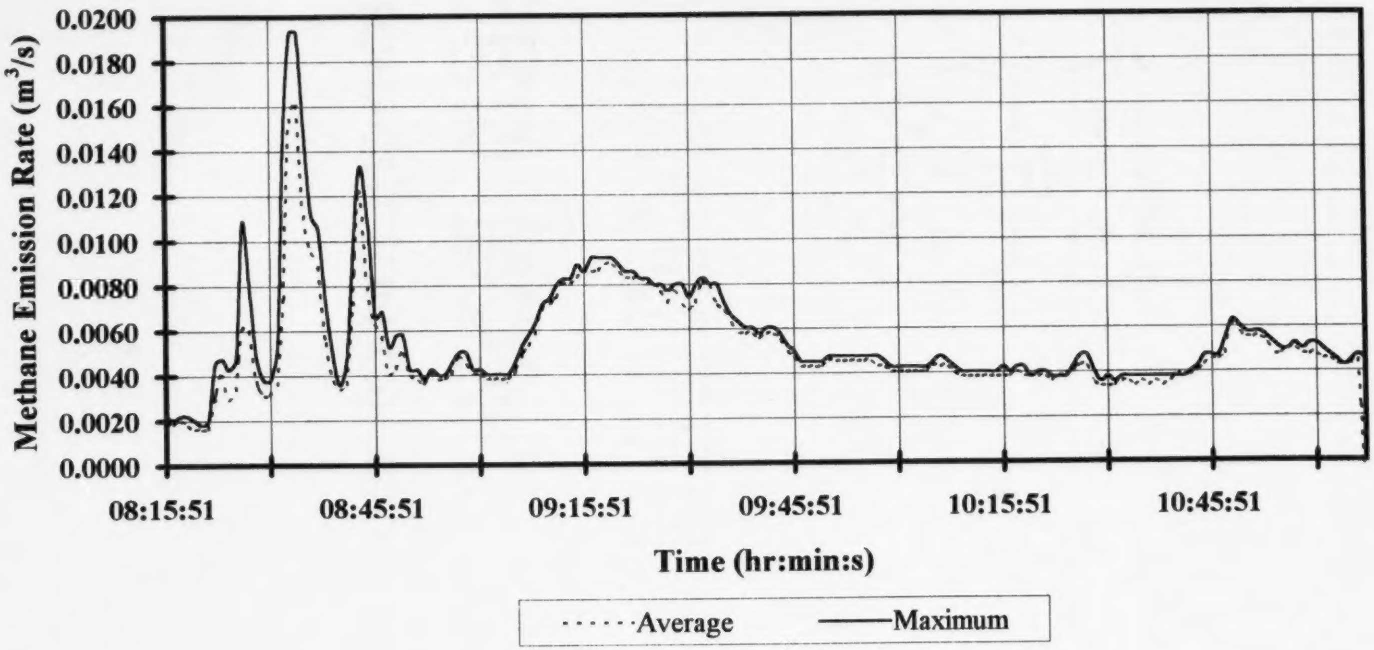


Fig. 4 - 30 Relationship between Methane Emission Rate and Time of Shift at Heading # 10

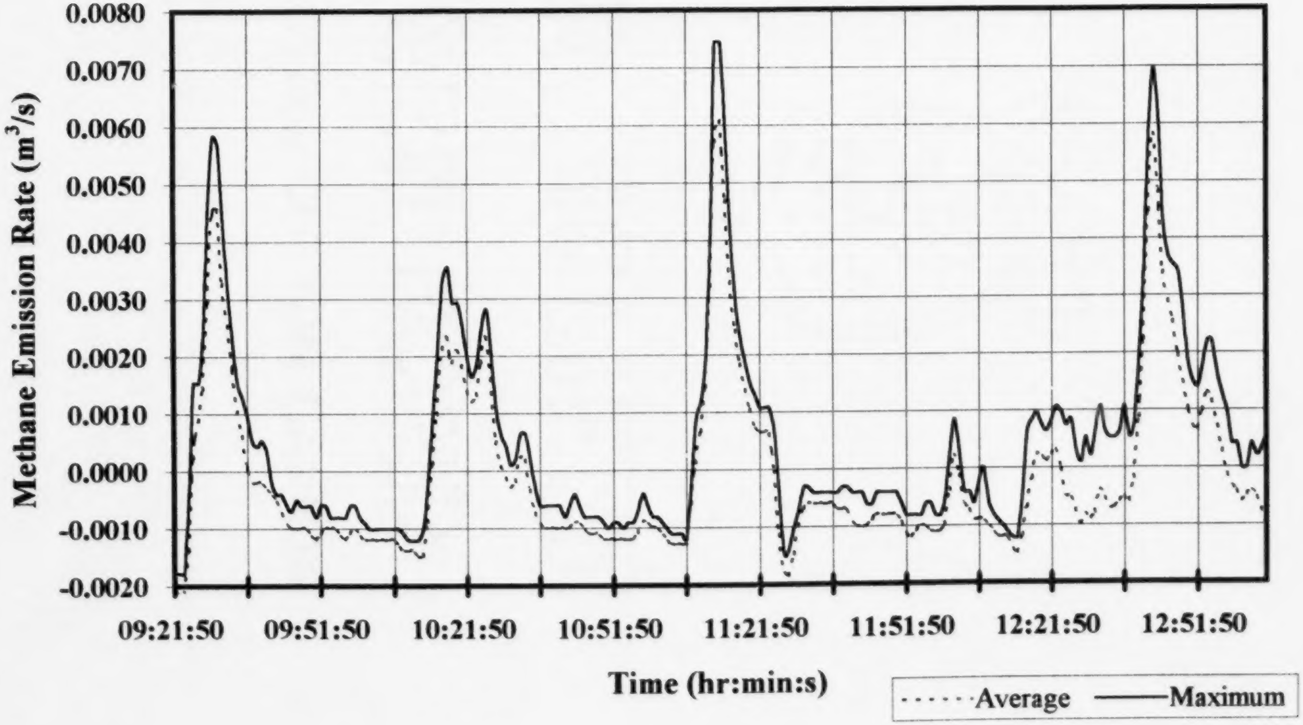
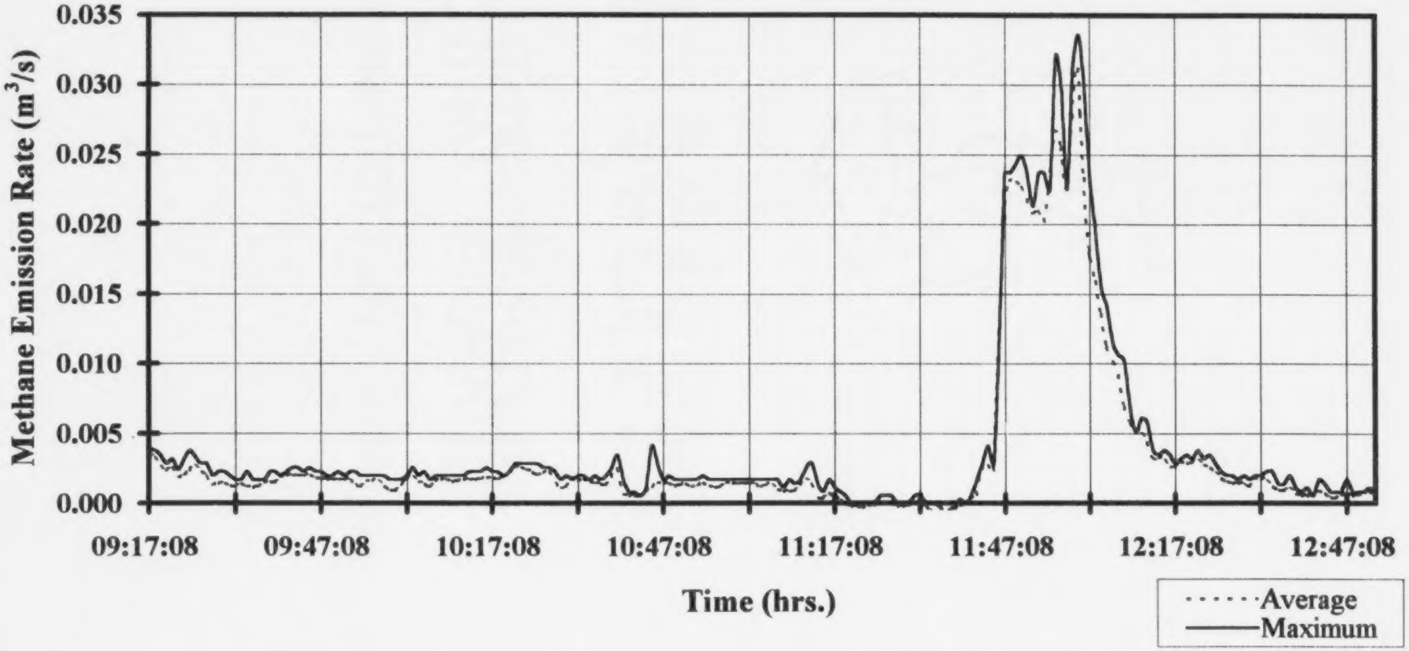


Fig. 4 - 31 Relationship between Methane Emission Rate and Time of Shift at Heading #11



The effectiveness of an auxiliary ventilation system in this work is understood to mean the ability of the system to control and maintain the concentration of a contaminant (such as methane) within acceptable levels in a heading and how quickly it can dilute (purge) the concentration of the contaminant from one level to another. Very effective auxiliary ventilation systems in coal mines are those that can maintain the methane concentration within acceptable limits and are able to cope with and purge high levels of methane concentration to statutory levels within a very short time (< 1 min.) as well as meet the requirements of exigencies (such as large and abnormal methane emission rates).

In the determination of the dilution requirements for a heading or roadway, some researchers [15] recommend that the peak values of the methane concentration reached during cutting be used as the initial methane concentration [C_o in equations (4 - 21) and (4 -22)] which has to be diluted to the statutory levels. This often leads to the calculation and design of auxiliary ventilation systems with excessive capacities culminating in unwarranted ventilation costs (*since cost of power is directly proportional to the cube of the quantities of air supplied*).

In this work, two different purging scenarios were considered in assessing the efficiencies and effectiveness of the various auxiliary ventilation systems:

Condition 1: The methane gas emanating from the strata is considered to be pure (100%) in concentration by volume and the concentration of methane in the return air is taken as that registered by the methane monitor in the return (outbye).

Condition 2: The methane gas concentration at the face is taken as that registered by the monitor at the face and the concentration of methane in the return air taken as that recorded by the return air monitor.

The times to dilute the concentration of the methane in the headings from one concentration to the other under the stated conditions were investigated. Also the quantities of fresh air required to purge the methane concentrations under Conditions 1 and 2 within 1 minute in the various headings studied were also calculated (Appendices C, D and E).

The efficiencies of the auxiliary ventilation systems in the headings under the foregoing conditions were then calculated by finding the ratio of the quantities of fresh air supplied to the heading (under the present conditions) to that which would have been required to dilute the methane concentration to the set levels within one minute (assuming thorough mixing of the gases). Details are contained in Appendices C to E.

Figs. 4 - 32 to 4 - 34 are graphs of purging times while Figs. 4 - 35 to 4 - 37 show the required quantities to dilute the methane concentrations within the stated limits in Conditions 1 and 2 at Heading Nos. 9 to 11 respectively. In Heading Nos. 9 and 11, the actual purging quantities were about the same as that required under Condition 2 (See Figs. 4 - 35 and Fig. 4 - 37). This means that in those headings the quantities of fresh air supplied was adequate for purging methane concentrations to set levels in cases of exigencies. In Heading #10 however, the actual quantity supplied was far below that required under Conditions 1 and 2 (Fig. 4 - 36).

Figs. 4 - 38 to 4 - 40 depict the variation of the purging efficiencies of the auxiliary systems with time at Heading Nos. 9 to 11. The average purging times under the two conditions at Heading Nos. 9 to 11 are given in Table 4 - 1 while the required quantities of air to purge the methane concentration from one level to the other within one minute under Conditions 1 and 2 are summarized in Table 4 - 2.

Table 4 - 1 Calculated Purging Times at Various Headings Under Conditions 1 and 2

Heading No.	Condition 1	Condition 2
	Average (min.)	Average (min.)
9	3.84	1.92
10	7.90	3.09
11	4.24	1.46

Fig. 4 - 32 Variation of Average Purging Times during Shift at Heading #9 (Conditions 1 and 2)

Mean of Purging Times (Condition 1) = 3.84 min. Standard Dev. = 0.44 min.
Mean of Purging Times (Condition 2) = 1.92 min. Standard Dev. = 0.77 min.

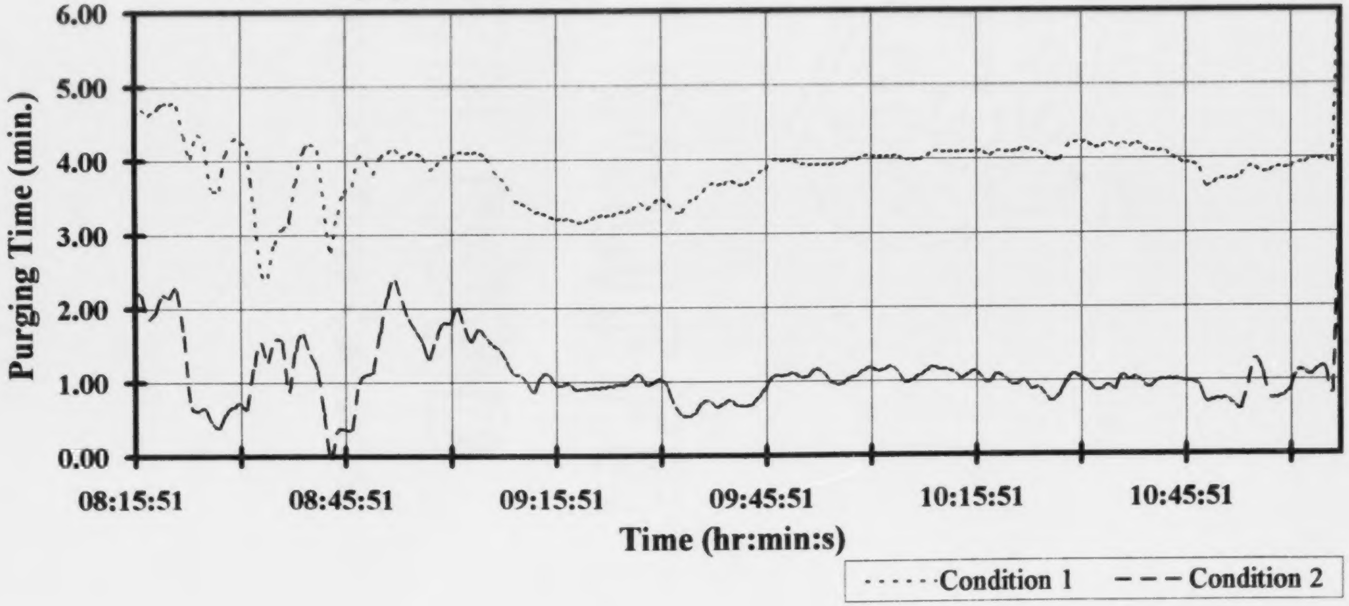


Fig. 4 - 33 Variation of Average Purging Times during Shift at Heading #10 (Conditions 1 and 2)

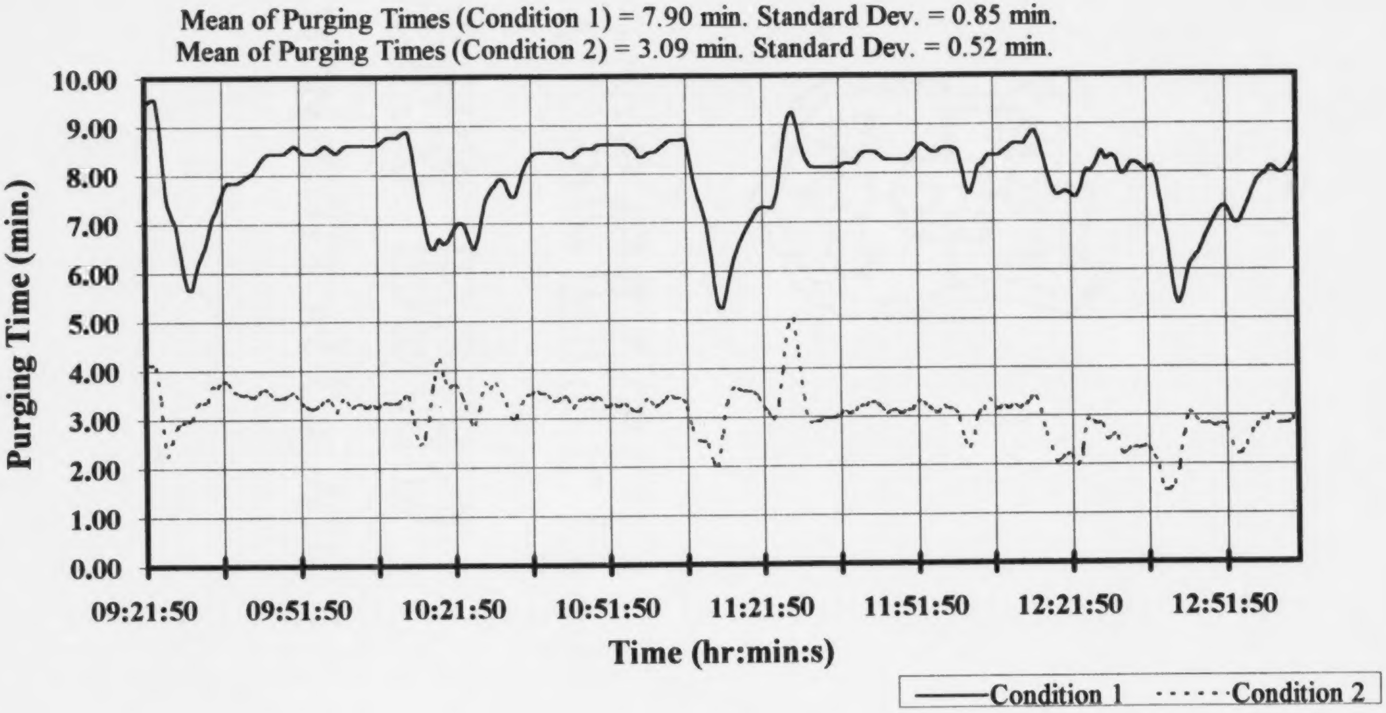

Mean of Purging Times (Condition 1) = 7.90 min. Standard Dev. = 0.85 min.
Mean of Purging Times (Condition 2) = 3.09 min. Standard Dev. = 0.52 min.

Fig. 4 - 34 Variation of Average Purging Time during Shift at Heading #11 (Conditions 1 and 2)

Mean of Purging Times (Condition 1) = 4.24 min. Standard Dev. = 0.70 min.

Mean of Purging Times (Condition 2) = 1.46 min. Standard Dev. = 0.89 min.

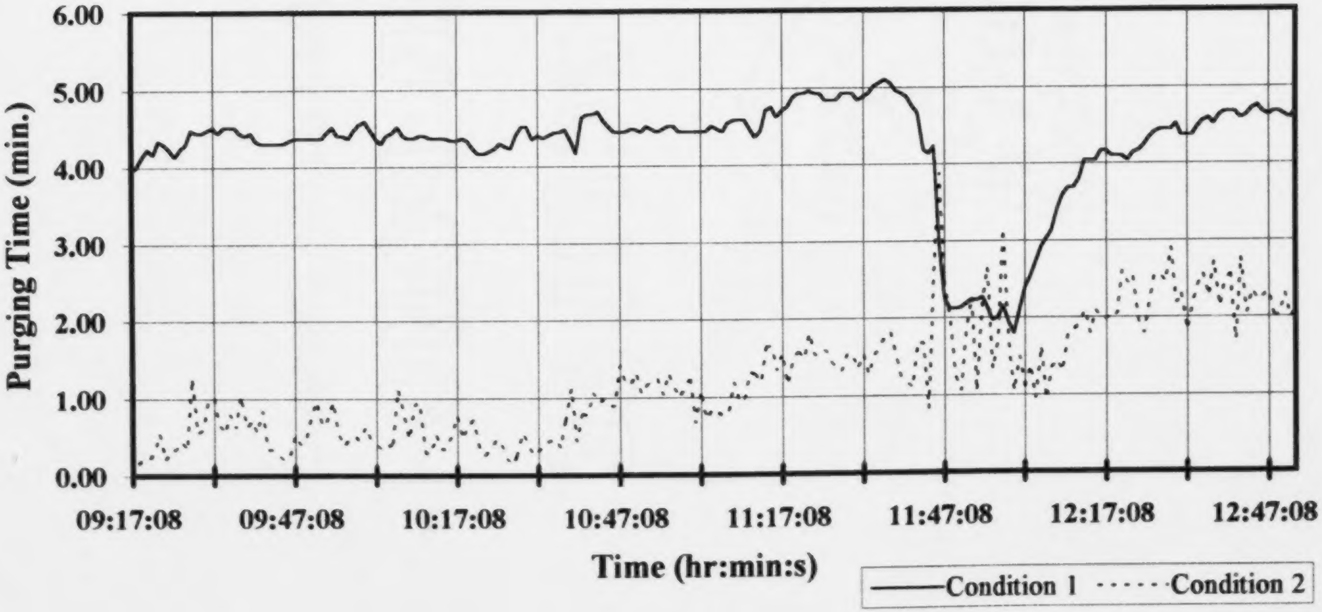


Fig. 4 - 35 Required Quantities of Intake Air to Dilute Methane Concentration to set Levels at Heading #9 (Conditions 1 and 2)

Mean Purging Quantity (Condition 1) = 26.03 m^3/s Standard Dev. = 2.98 m^3/s
Mean Purging Quantity (Condition 2) = 7.35 m^3/s Standard Dev. = 2.94 m^3/s

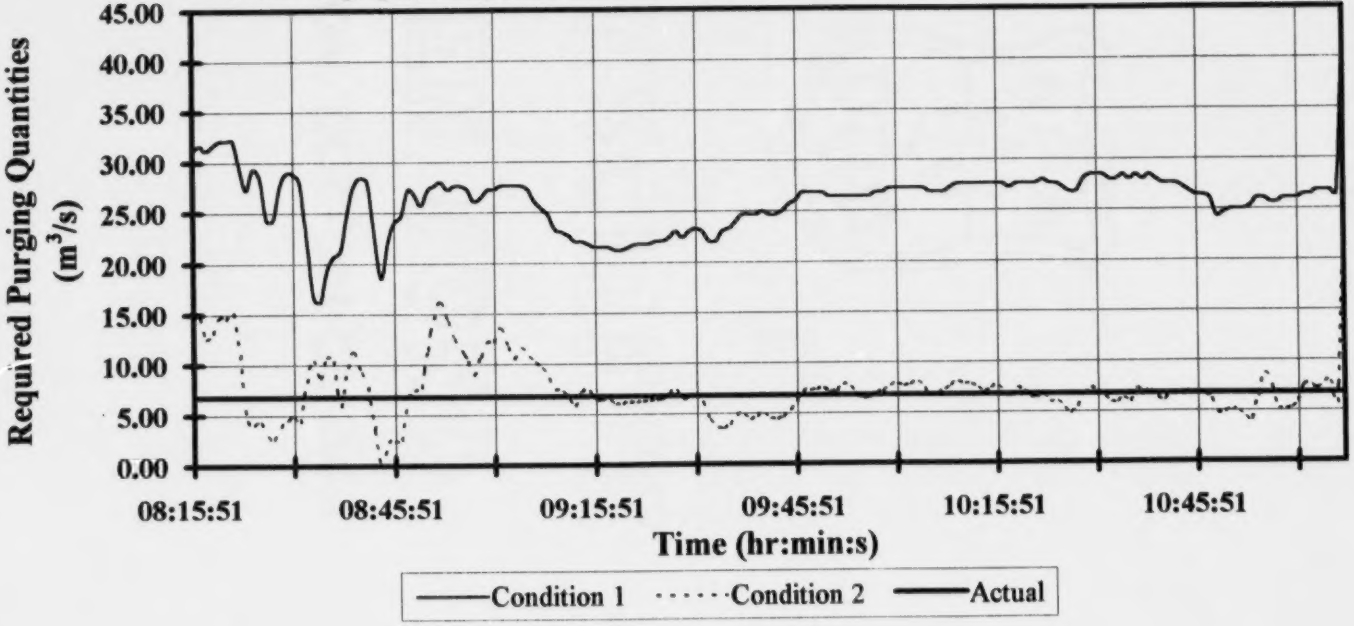
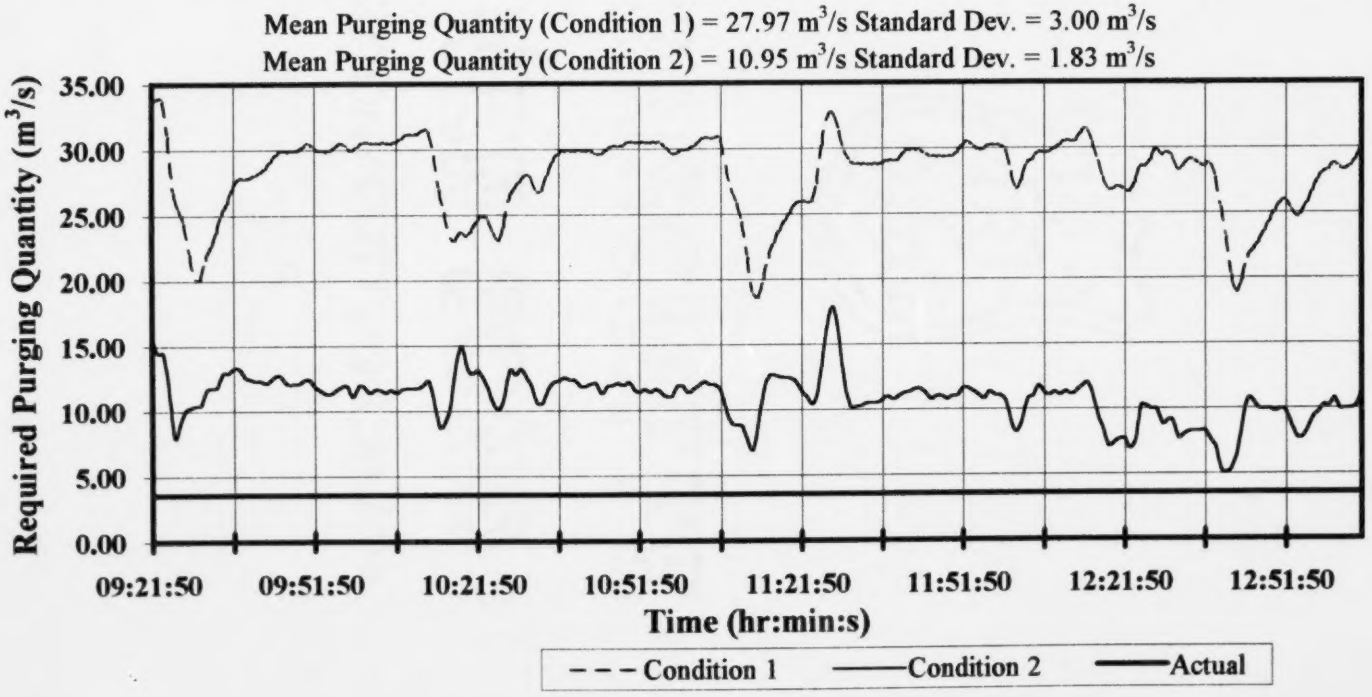


Fig. 4 - 36 Required Quantities of Intake Air to Dilute Methane Concentration to set Levels at Heading #10 (Conditions 1 and 2)



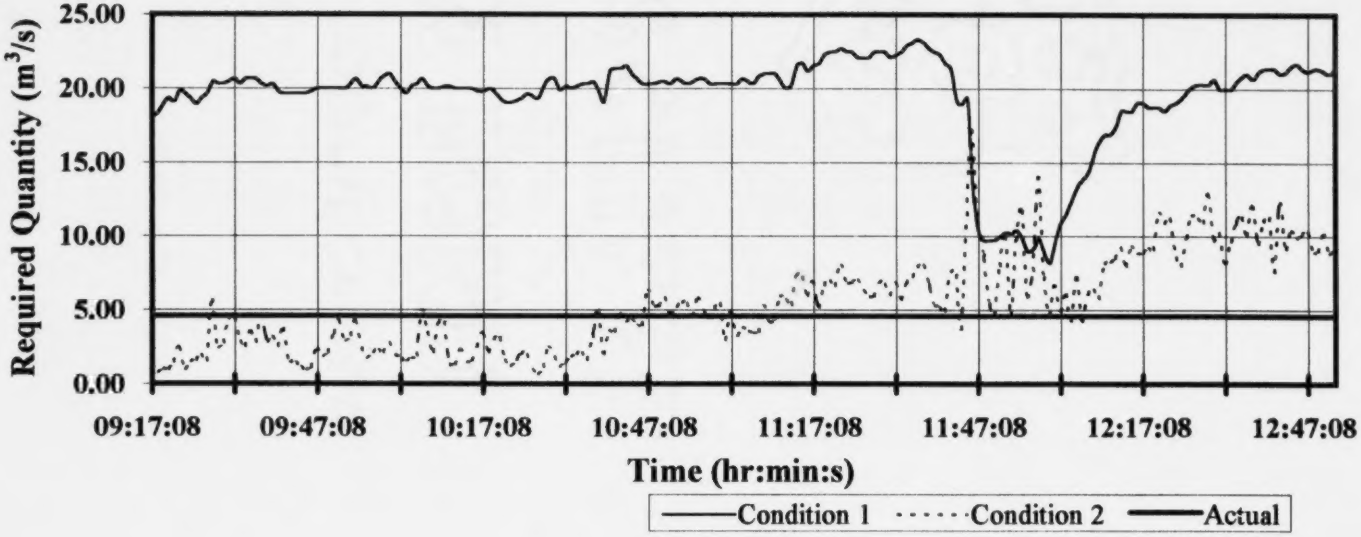


Fig. 4 - 37 Required Purging Quantities of Intake Air to Dilute Methane Concentration to set Levels at Heading #11 (Conditions 1 and 2)

Mean of Average Purging Quantities (Condition 1) = 19.38 m^3/s Standard Dev. = 3.21 m^3/s

Mean of Average Purging Quantities (Condition 2) = 5.43 m^3/s Standard Dev. = 3.29 m^3/s

Fig. 4 - 38 Variation of Purging Efficiencies with Time during Shift at Heading #9 (Conditions 1 and 2)

Mean Purging Efficiency (Condition 1) = 26.38% Standard Dev. = 3.28%
Mean Purging Efficiency (Condition 2) = 89.19% Standard Dev. = 215.86%

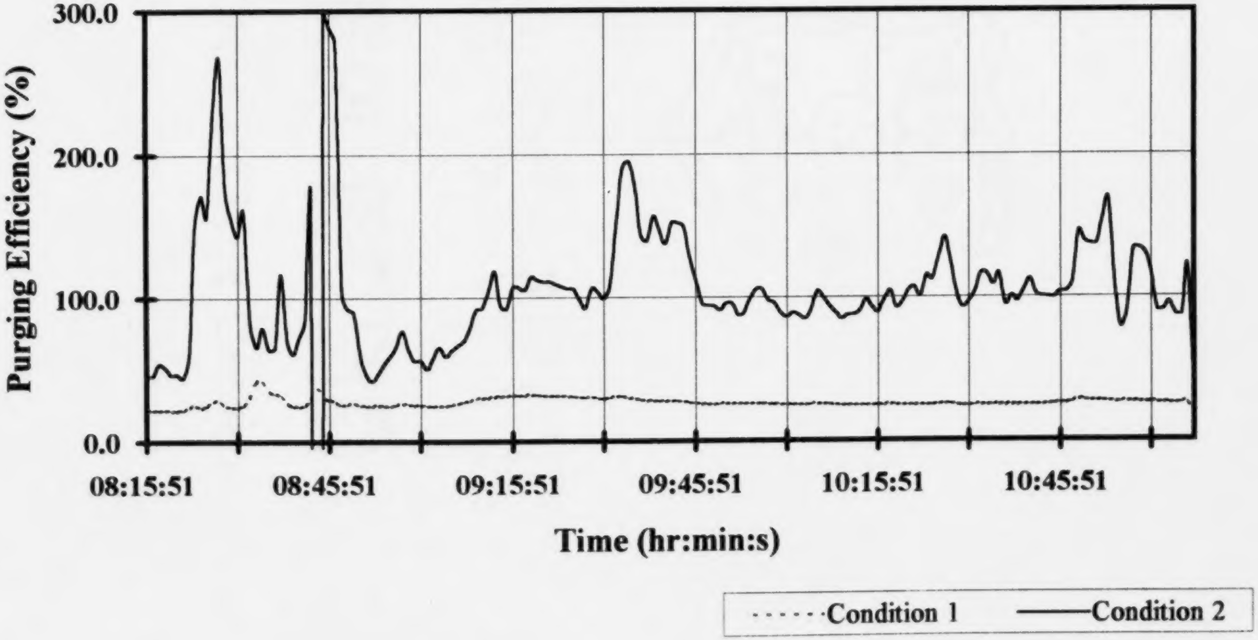


Fig. 4 - 39 Variation of Purging Efficiencies with Time during Shift at Heading #10 (Conditions 1 and 2)

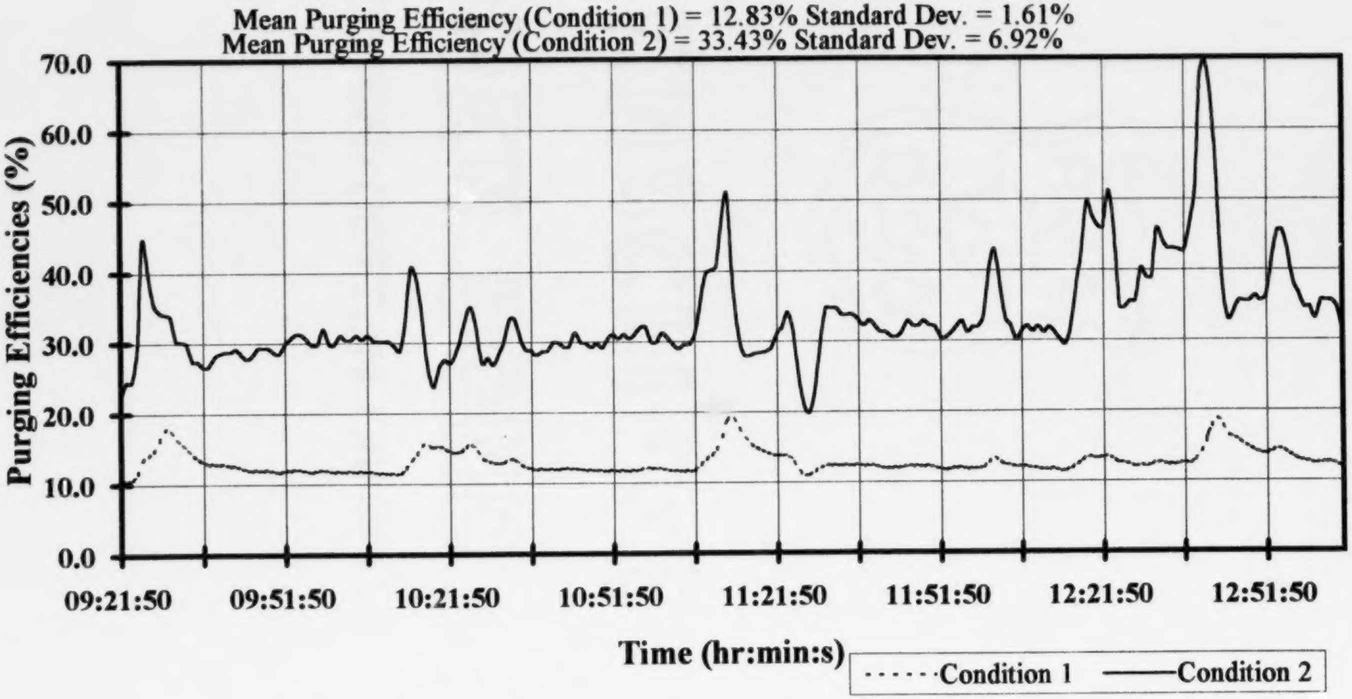
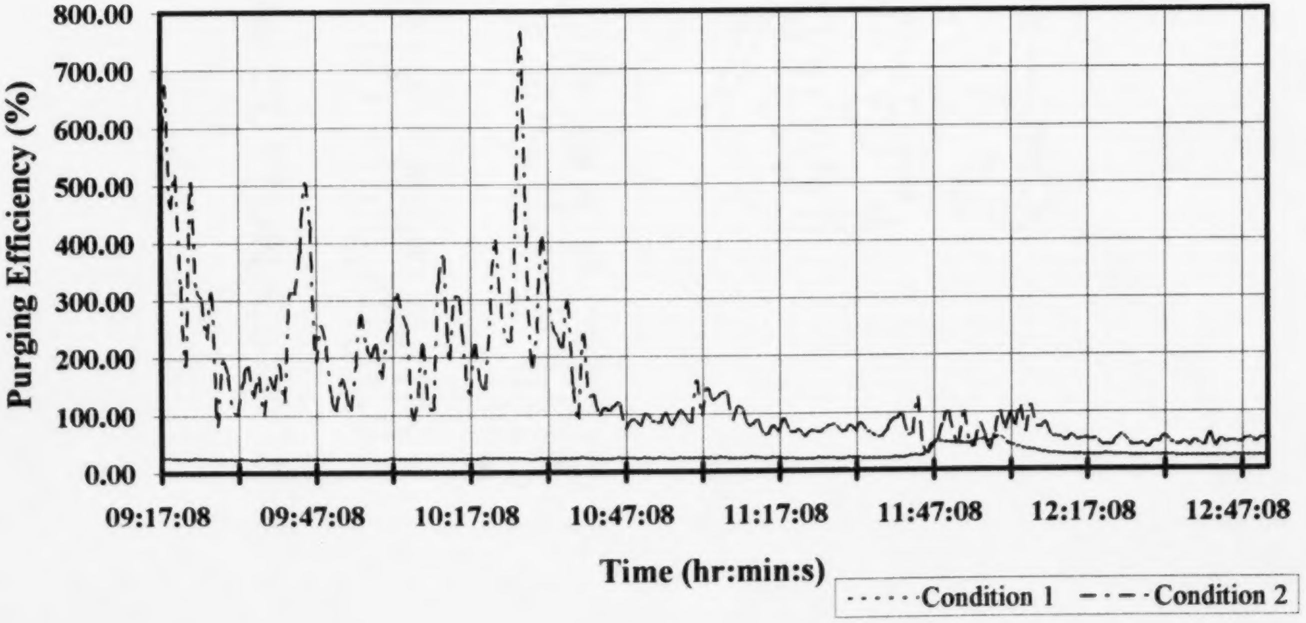


Fig. 4 - 40 Relationship between Purging Efficiencies and Time of Shift at Heading #11 (Conditions 1 and 2)

Mean Efficiency (Condition 1) = 24.92% Standard Dev. = 6.93%

Mean Efficiency (Condition 2) = 138.78% Standard Dev. = 119.16%



From the results in Table 4 - 1, the average purging times in Condition 1 varied from 3.84 minutes in Heading #9 to 7.90 minutes in Heading #10. In Condition 2, the average purging times in the headings ranged from 1.46 minutes in Heading #11 to 3.09 minutes in Heading #10.

Table 4 - 2 Required Purging Quantities to Dilute Methane Concentrations to Various Levels in One Minute

Heading No.	Condition 1	Condition 2	Actual Quantity
	Average (m^3/s)	Average (m^3/s)	(m^3/s)
9	26.03	7.35	6.77
10	27.97	10.95	3.54
11	19.38	5.43	4.57

From Table 4 - 2, the required purging quantities are much higher in Condition 1 in all headings because the methane gas is diluted over a much wider range in concentration than in Condition 2.

4.4 Tracer Gas based Auxiliary Ventilation Surveys

In addition to the air quantity and air velocity measurements that were done by means of traditional anemometry, pitot tubes and smoke cloud methods, tracer gas based techniques were also employed in the evaluation of the auxiliary ventilation systems in selected development headings. Tracer gas based techniques have been used extensively in the study and evaluation of mine ventilation systems ranging from leakages and recirculation through gobs, pressure-volume surveys, fan testing, shaft and ventilation raise surveys [38], air transit time through large-scale mine networks and air exchange rates in indirectly ventilated headings [39] to mention a few. Tracer gas methods are superior to traditional methods in accuracy and versatility in application in irregular, inaccessible or highly turbulent flow situations, geometrically complicated and highly obstructed mine openings [38].

Numerous organic or inorganic substances like nitrous oxide, helium, carbon dioxide, the freons (freon-12 and freon-13B) and radioactive gases have been used as tracer gases but the predominant one has been sulphur hexafluoride (SF_6) gas. The tracer gas is usually mixed with the ventilation airstream in order to trace and study the progress of the airstream through a mine network. The assumption is that there is thorough mixing of the tracer gas and the airstream and they behave aerodynamically in an analogous manner.

Unlike most other chemical and radioactive tracers, which are readily absorbed on the surfaces of the mine openings, are difficult to handle, are not easily detectable at low concentrations and their use may be a health risk to workers, SF_6 is a colorless, odorless, chemically and thermally stable compound which is easily transportable and detectable at very low concentrations (a few parts per trillion range) but most importantly, does not normally occur in the mine environment [38, 39].

4.4.1 Tracer Gas Techniques

All tracer gas techniques employ three basic operations [39]:

1. Tracer gas release.
2. Gas sampling.
3. Tracer gas analysis.

.1 Tracer Gas Release Methods

There are two main tracer gas release methods employed in mine ventilation surveys [9, 39]:

a) Steady release methods and
b) Pulse-release methods.

In the steady state release method, the tracer gas is released continuously at a constant volume flow rate at the release point and individual air samples are taken at various locations downstream where the tracer gas is believed to be uniformly mixed with the airstream. The concentration of the tracer gas in the air samples is later determined by gas analysis (*described in a later section*). The volume of air flow is determined from the simple equation [9, 40]:

$$Q = \frac{R}{C} \times 1000 \qquad (4 - 25)$$

where Q = volume flow rate of air at measuring point, m^3/s

R = volume flow rate of tracer gas, cc/s

C = concentration of tracer gas in the sample, in parts per billion (ppb)

The premise of equation (4 - 25) is that there are no losses of the tracer gas between the point of release and the sampling points.

In the pulse-release method, a known mass of the tracer gas is released instantaneously into the airstream at the release point and air samples are taken at frequent intervals downstream at various measuring points over a period of time until the concentration of the tracer gas in the airstream is negligible [9, 39]. Profiles of the concentration of tracer gas as a function of time at the various measuring points are then plotted and the area under the curve is determined and used in calculating the ventilation parameters. The quantity of air flowing through any point in the mine airway is given by:

$$Q = \frac{M}{\rho A} \qquad (4 - 26)$$

where Q = volume flow rate of air through section, m^3/s

M = Mass of tracer gas released into airstream, kg

ρ = the density of the tracer gas, kg/m^3

A = Area under the curve (in seconds).

The difference in mass of the "lecture" bottle that contains the tracer gas before and after it is released into the airstream gives the mass of tracer gas released into the airstream in equation (4 -26).

.2 Tracer Gas Sampling Techniques

Mine air samples are routinely collected for analysis using a variety of metal, glass and plastic containers [39, 40]. The most common containers employed in collecting grab air samples in routine tracer gas measurements underground are 30 or 60 cc plastic disposable syringes, Tedlar sampling bags and 10 cc vacuum tubes (*similar to those used to extract blood samples*). Samples taken in these containers can be easily extracted and laboratory tests have indicated that the tracer gas concentrations remain stable for periods ranging from 24 hours in the plastic syringes to 10 days in the vacuum tubes [38, 39].

The number of tracer gas samples taken during any tracer gas test is determined mainly by the type of test and the prevailing conditions in the section [39]. The sampling intervals are chosen as to give a well-defined response profile in the plots of the tracer gas concentration versus time at each location (particularly if the pulse-release method is being employed).

.3 Techniques in Tracer Gas Analysis

Several techniques have been employed by research and analytical laboratories in the analysis of tracer gas samples. However tracer gas samples are mainly analyzed by gas chromatography combined with electron capture detectors [39, 41]. These systems are capable of analyzing SF_6 concentration from 50 parts per trillion to 5 parts per million [38].

4.4.2 Application of Tracer Techniques in Present Study

Tracer gas techniques were employed in this work with the ordinary light bulb test to determine the decay rate of the SF_6 gas in the face of the heading and interpreting this to indicate the rate of dilution of methane produced at the face to set levels (*assuming that the SF_6 simulates the behavior of methane*) and in the determination of air flow rates through ventilation ductings, resistances, leakages and other auxiliary ventilation parameters and system efficiencies (*flume tests*) in the auxiliary ventilation systems studied.

.1 Airflow Measurements in Auxiliary Ventilation Systems

In order to assess the volumetric flow rates through certain portions of the ventilation ducting in the development headings in this study, pitot tubes were employed because traditional anemometric techniques were found to be either inapplicable or unsuitable due to the high degree of inaccuracies resulting from the high level of turbulence, complicated geometry or inaccessibility to the zones. Thus tracer gas techniques, which have been used extensively with satisfactory results in many mines under different ventilation conditions [38], were employed to study the auxiliary ventilation systems in some of the headings covered in this work.

Volumetric flow rate measurements (*also referred to as flume tests*) were done by injecting a steady stream of SF_6 into the center of the main auxiliary ventilation ducting at selected distances [usually at 61 m (200 ft) intervals] along the length of the ducting in the heading. The precisely regulated tracer gas streams were rapidly and thoroughly mixed with the airstream within the ducting. The release rate during the survey was usually measured at the ambient mine air conditions by means of a soap bubble flowmeter before and cross-checked at the end of the volumetric flow tests [31]. Samples of the air discharged at the end of the ducting were taken with 30 cc disposable syringes at suitable intervals (15 to 30 seconds) over predetermined intervals. Injections of the tracer gas into the ducting proceeded from the discharge end of the ducting towards the main auxiliary ventilation fan. Concentrations of the tracer gas in the airstream are assumed to be uniform about 50 m downstream from the point of injection [38]. By means of a pitot tube and either a water gauge or a magnehelic pressure gauge, the static pressure heads at the points of the ducting (*where SF_6 gas injections were done*), were measured. The ambient temperatures of the mine air were also measured and recorded.

At the end of the tests, the air samples were sent up to the laboratory and analyzed within 24 hours by gas chromatography utilizing an electron capture detector. From the chromatographically determined concentrations of the tracer gas samples (usually stated in parts per billion) from the flume tests, the volumetric flow rates at the various points along the auxiliary ventilation ductings were calculated using equation (4 - 25) [See Table 4 - 3].

Table 4 - 3 Auxiliary Ventilation Survey at Heading #9 (August 30, 1994)

No.	Run	Time (hr:min:s)	SF_6 conc. (ppb)	Average SF_6 conc. (C, ppb)	Air Quantity (m^3/s)
1	45	11:11:00	264	264.67	2.58
2	46	11:11:30	264		
3	47	11:12:00	266		
4	48	11:22:00	237	238.67	2.87
5	49	11:22:30	239		
6	50	11:23:00	240		
7	51	11:32:00	161	161.67	4.23
8	52	11:32:30	161		
9	53	11:33:00	163		
10	56	11:42:00	156	156.67	4.37
11	57	11:42:30	157		
12	58	11:43:00	157		
13	59	11:53:00	140	140.00	4.89
14	60	11:53:30	140		
15	61	11:54:00	140		
16	62	12:03:00	131	131.00	5.22
17	63	12:03:30	131		
18	64	12:04:00	131		
19	66	12:18:00	94	94.00	7.28
20	67	12:18:30	94		
21	68	12:19:00	94		
22	69	12:34:00	79	79.00	8.66
23	70	12:34:30	79		
24	71	12:35:00	79		
Rate of SF_6 release (R cc/s)		0.684	(41.00 cc/min)		
Q (m^3/s)		R/C	$684/SF_6$		

Equipped with the volume flow rates, the pressure gauge readings as well as the temperature of the ambient mine air, other auxiliary ventilation parameters such as the static pressure losses, resistance of the ventilation ducting per given length, the amount of leakages between the various points along the ducting, and the efficiency of the systems were calculated using available mine ventilation software such as AVSURVEY.BAS [31].

Table 4 - 4 shows the type of measurements done during the flume tests at Heading # 9 on August 30, 1994 while Table 4 - 5 gives the numerical output from the auxiliary ventilation survey.

Table 4 - 4 Auxiliary Ventilation Flume Test at Heading #9

Sample Nos.	Location	Distance from Fan	Distance from Fan	Static Pressure	Air Quantity	Air Quantity
		(m)	(ft)	(in Wg.)	(m^3/s)	(cfm)
22 - 24	820#	0	0	15.2	8.66	18342
19 - 21	1020	200	656	10.7	7.28	15419
16 - 18	1220	400	1312	6.0	5.22	11056
13 - 15	1420	600	1969	4.3	4.89	10357
10 - 12	1620	800	2625	2.7	4.36	9234
7 - 9	1820	1000	3281	2.0	4.25	9002
4 - 6	2020	1200	3937	1.2	2.86	6057
1 - 3	2220	1400	4593	0.8	2.58	5464
	2414*	1594	5229			

* End of Duct # Fan location

From the flume tests the amount of leakage that occurs in the auxiliary ventilation ductings can be quantified and the efficiencies of the overall systems calculated. The overall efficiency of the system from the flume test was calculated to be about 29%, which falls within the range of 20.63% to 73.45% in overall efficiencies calculated over the period December 1993 to August 1994 for Heading #9 (See Appendix B - 7 and Fig. 4 - 18) and discussed in depth earlier on in Section 4.2.2. The values given in Appendix B - 7 are however generally higher than that obtained from the flume test because the amount of leakage (Q_l) in the ductings could not be quantified and was assumed to be negligible in the calculations using equations (4 - 3) and (4 - 4).

Table 4 - 5 Auxiliary Ventilation System Parameters from Flume Test at Heading #9 (August 30, 1994)

Location	Distance from Fan (m)	Distance from Fan (ft)	Static Pressure (in. Wg)	Air Quantity (m^3/s)	Static Pressure (Pa)	Average Flow (m^3/s)	Pressure Drop (Pa)	Leakage (m^3/s)	Resistance Per 15 m (Ns^2/m^8)	Leakage Resistance (Ns^2/m^8)	Leakage Resistance Per 15 m (50 ft) (Ns^2/m^8)
820	0	0	15.2	8.66	3782	8.66	0.00	0.00	0.00	0.00	0.00
1020	200	656	10.7	7.28	2663	7.97	1120	1.38	1.34	1691	128.87
1220	400	1312	6.0	5.22	1493	6.25	1170	2.06	2.28	490	37.34
1420	600	1969	4.3	4.89	1070	5.06	423	0.33	1.26	11775	896.16
1620	800	2625	2.7	4.36	672	4.63	398	0.53	1.42	3103	236.47
1820	1000	3281	2.0	4.25	498	4.31	174	0.11	0.72	48359	3685.93
2020	1200	3937	1.2	2.86	299	3.56	199	1.39	1.20	206	15.72
2220	1400	4593	0.8	2.58	199	2.72	100	0.28	1.03	3176	242.07
2414**	1594	5230									

2 x 55.95 kW (75 Hp) Engart Fan Operating at 3.78 kPa (15.2 in. Wg) and 8.66 m^3/s (18341 cfm)

Resistance/15 m (50ft) (Ns^2/m^8): Minimum = 0.71 Maximum = 2.28 Average = 1.32

Leakage Resistance/15 m (50ft) (Ns^2/m^8): Minimum = 15.71 Maximum = 3685.92 Average = 748.93

Overall System Efficiency = 29%

** - Duct End

- Fan Position

Figs. 4 - 41 to 4 - 46 are plots of air quantity, static pressure, leakages and leakage resistance, etc., of auxiliary ventilation ducting with distance at Heading #9. A number of observations on the system performance may be made from these plots.

In Figs. 4 - 41 and 4 - 42 the zones of maximum decrease in air flow rates and static pressure gradients indicate areas of high air leakages. For example, in Fig. 4 - 41 the length of the ducting from the main auxiliary forcing fan to a distance of about 400 m showed substantial drops in air quantity from about 8.66 to 5.22 m^3/s and from Fig. 4 - 42, this led to a drop in static pressure from 3.78 kPa to 1.49 kPa (*more than 50% drop in the original static pressure over a distance of only 400 m*). This suggested that there was quite a substantial amount of air leakage through the auxiliary ventilation ducting within that zone. This suspicion is confirmed by the high values in the columns of the histogram between 200 and 400 m in Fig. 4 - 43. Fig. 4 - 41 also indicates another zone of high leakages at a distance of about 1000 to 1200 m from the fan. This is again confirmed by the high column at the 1200 m mark in Fig. 4 - 43.

The fact that high amounts of leakages in any ventilation system lead to drastic static pressure losses in the system is confirmed by the high columns in the histogram in Fig. 4 - 44 within 400 m from the fan. Figs. 4 - 45 and 4 - 46 indicate that areas of high leakages have little or no resistance to the flow of air and hence the leakage resistances of the ducting in zones of profuse leakages are usually very low (points 200 to 400 m from fan and also at 1200 m from the fan in Figs. 4 - 45 and 4 - 46).

The foregoing discussion on the graphs generated from the results of the flume tests in auxiliary ventilation ductings and the observations that can be made from them can assist the ventilation engineer to easily locate problem areas along the ventilation ducting in headings (which are often very long) and take remedial action on them to improve the efficiency of the air supply and distribution system in the heading and to improve the safety and working conditions in such headings.

Fig. 4 - 41 Variation of Air Quantity along the Auxiliary Ventilation Ducting at Heading #9

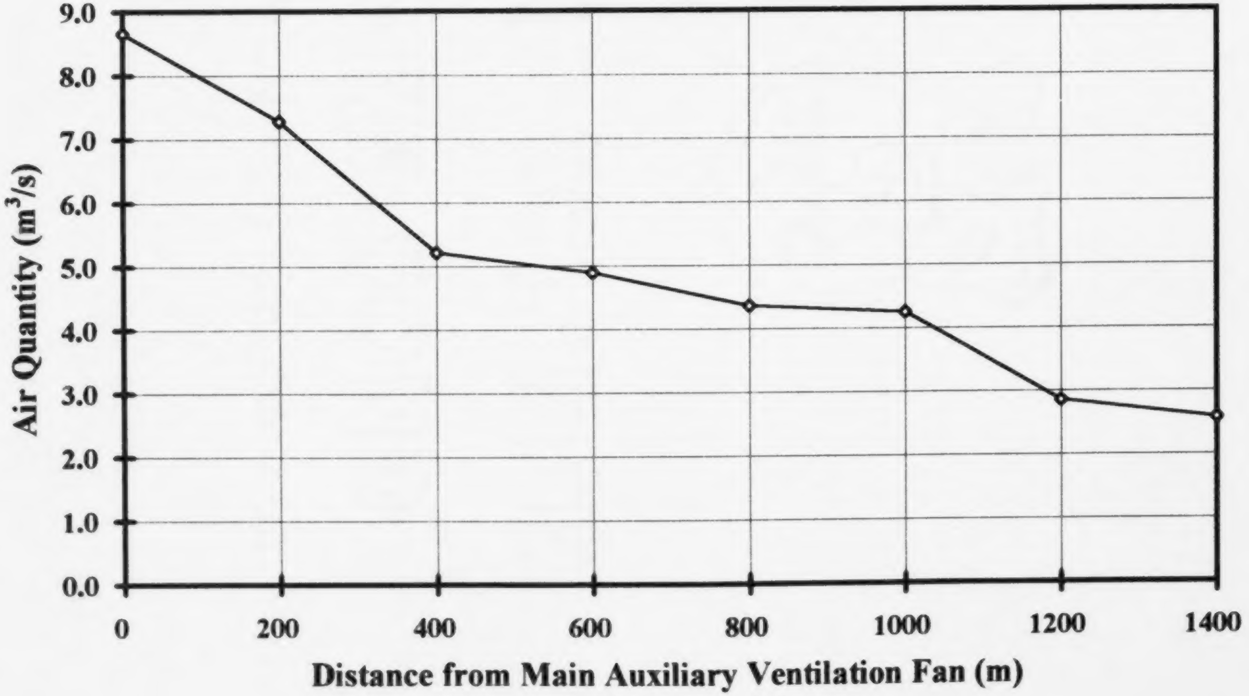


Fig. 4 - 42 Variation of Static Pressure along Ducting at Heading #9

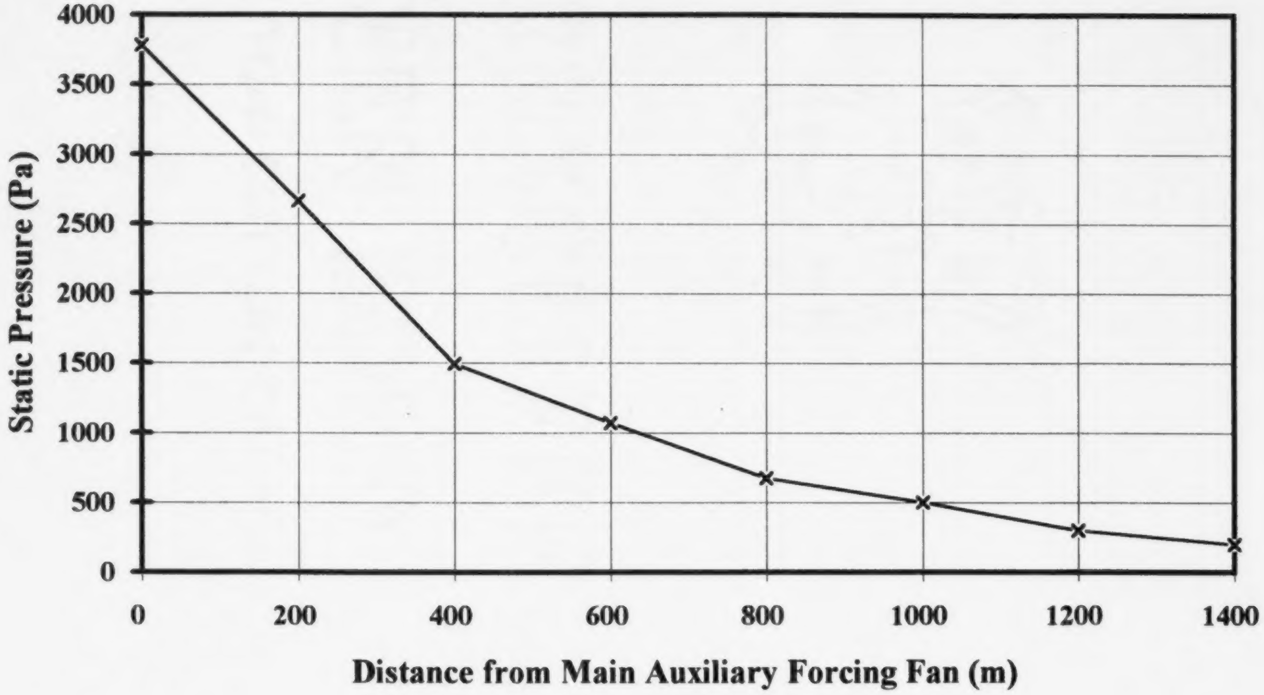


Fig. 4 - 43 Variation of Leakages along Auxiliary Ventilation Ducting at Heading #9

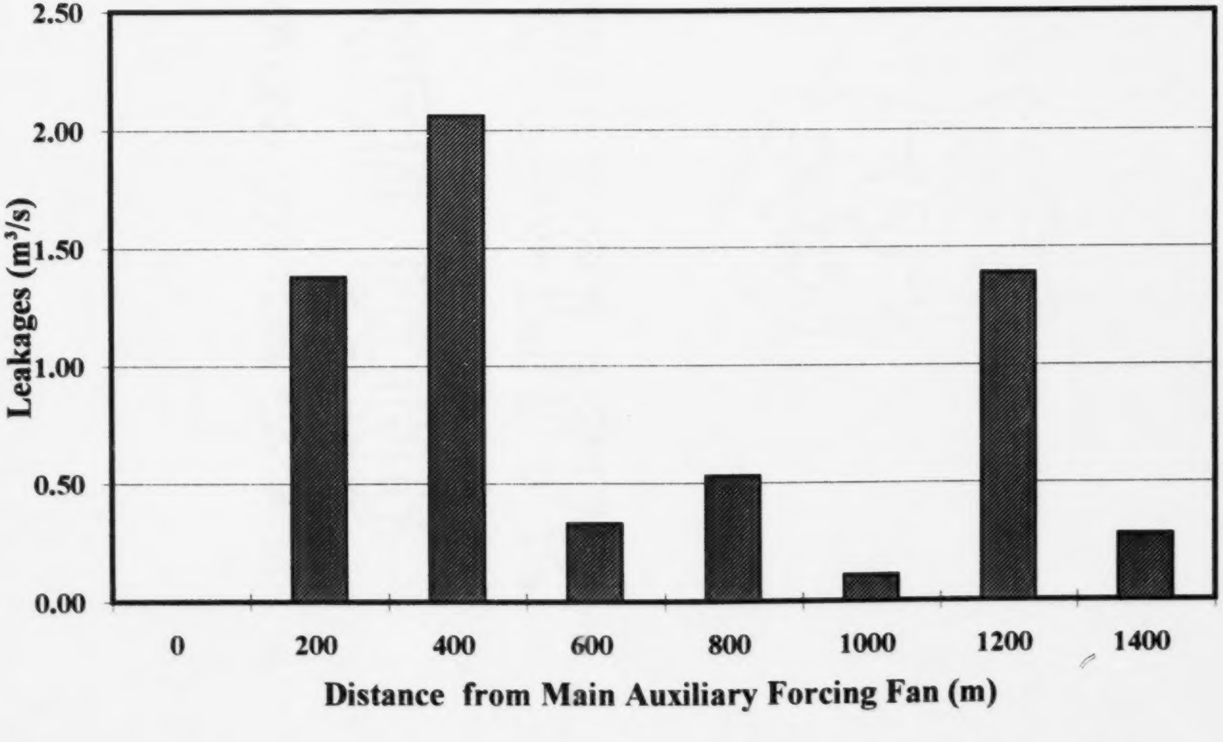


Fig. 4 - 44 Variation of Pressure Loss along Auxiliary Ventilation Ducting at Heading #9

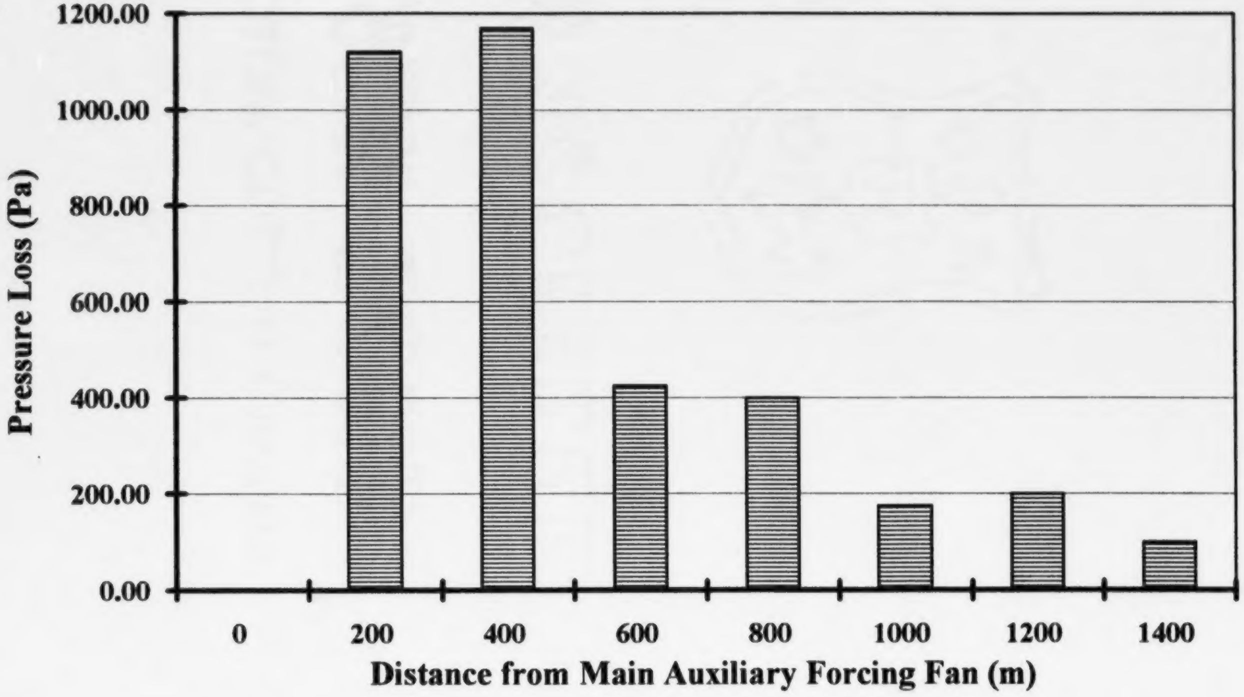


Fig. 4 - 45 Variation of Resistance of Auxiliary Ventilation Ducting with Distance at Heading #9

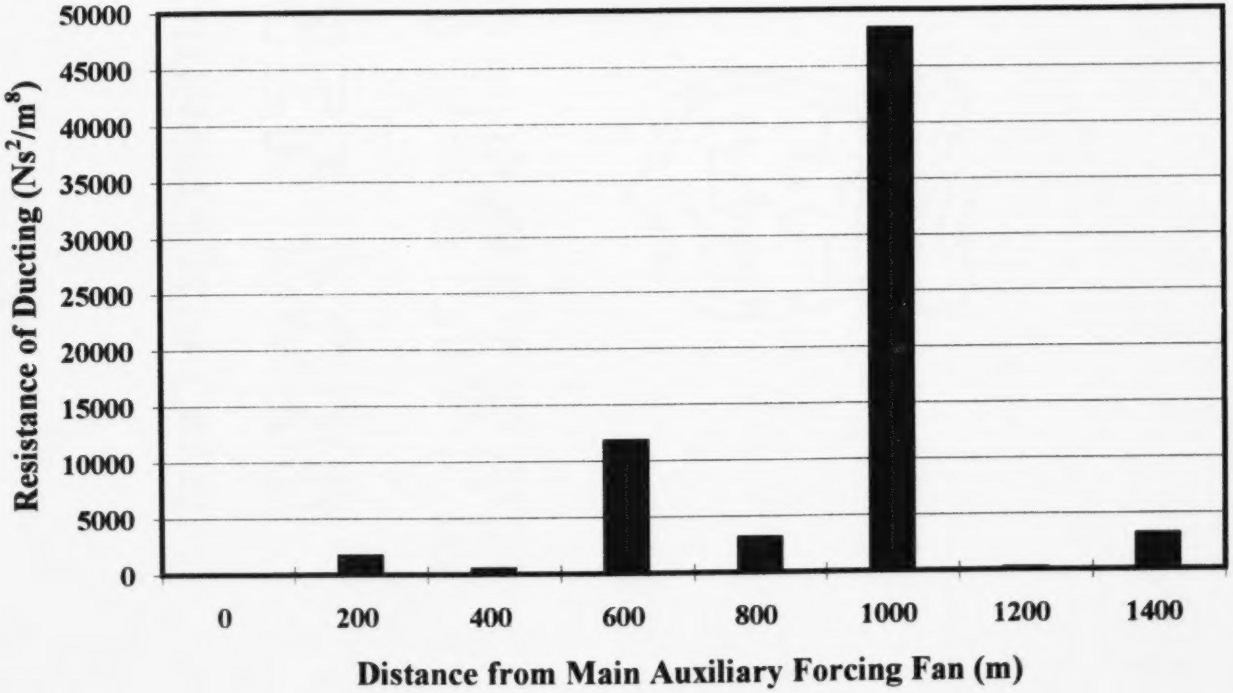
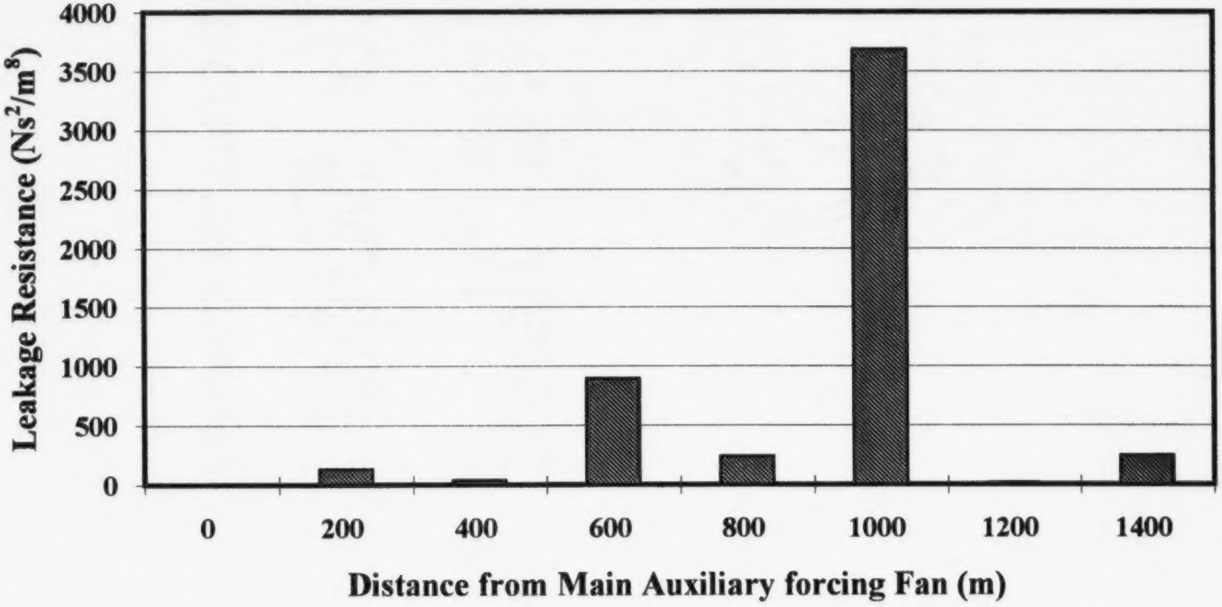


Fig. 4 - 46 Relationship between Leakage Resistance of Auxiliary Ventilation Ducting and Distance from Fan at Heading #9



.2 Methane Concentration Dilution Rate Test by means of Tracer Gas in a Light Bulb

Tracer gas based techniques were also employed to determine the rate of dilution of methane gas in development headings. This involved methods of measuring the rate of decay in the concentration of SF_6 with time in the headings. This was done by injecting pure (100%) SF_6 into a standard size light bulb ($\approx$ 125 ml in volume) in the laboratory. Before the tests were conducted two samples of the air in the development heading were taken to give the background values. When cutting of coal was proceeding at the face leading to an increase in concentration of the methane at the face, the light bulb was thrown against the coal at the face. This action broke the light bulb and released a pocket of SF_6 into the mine air at the face. Air sampling, by means of 30 cc plastic syringes, was done at the end of the control volume (about 60 m from the face) at 15 seconds intervals in the first two minutes and at 30 to 60 seconds intervals after that. Sampling of the mine air was done until the concentration of the SF_6 in the air is presumed to be negligible. The temperature and pressure of the air in the heading were also taken. The air samples were later sent up to the laboratory and analyzed by methods described earlier on.

In this test, it was assumed that under the ventilation conditions at the face of the heading, the time to dilute and disperse a pocket of SF_6 at the face to negligible concentrations closely represents the dilution of a pocket of methane at the face to certain safe concentrations (*assuming that the SF_6 simulates the behavior of methane in the heading*).

The following relation is used to determine the decay rate of the tracer gas (hence the air exchange rate, λ) in the heading [39]:

$$\lambda = \frac{1}{t}\ln\left(\frac{C_0}{C_1}\right) \qquad (4 - 27)$$

where C_o = tracer concentration at time t_o, in ppb

C_1 = tracer concentration at time t_1, seconds

t = time interval between t_1 and t_o (i. e. $t_1 - t_0$), seconds

By making t in equation (4 - 27) the subject of the equation, we obtain:

$$t = \frac{1}{\lambda} \ln\left(\frac{C_0}{C_1}\right) \qquad (4\text{-}28)$$

Equation (4 - 27) may also be expressed as:

$$\ln C_1 = \ln C_0 - \lambda t \qquad (4 - 29)$$

Equations (4 - 28) and (4 - 29) may then be employed to calculate the time required for any concentration of gas to be diluted from one level to the other.

Figs. 4 - 47 to 4 - 49 are plots of the decay profiles of SF_6 at Headings 9 to 11 (data given in Appendix G - 1). Figs. 4 - 50 to 4 - 52 show the natural logarithm profiles of the tracer gas decay rates in Headings 9 to 11. In Fig. 4 - 47, the concentration of the tracer gas was negligible after about 240 seconds (4 min.), while those in Figs. 4 - 48 and 4 - 49 were 480 seconds each.

For accurate determination of the purging times, two separate approaches may be employed:

1. Where the methane concentrations are known, the first approach involves determining the gradient of the log concentration-time graphs in Figs. 4 - 50 to 4 - 52, and inserting these together with the concentrations of methane at times t_1 and t_o into equation (4 - 28) [39].
2. Where the methane concentrations are not known, it is required to find the gradient of the log concentration-time graphs as well as the point of intersection on the ordinate axis (log axis). By plugging these values into equation (4 - 29) and solving for the time, t, when $C_1 = 0$ or equal to the background concentration of SF_6, the purging time for the SF_6 (hence that of methane gas in the heading) is obtained.

As the methane concentrations were measured (known) in this study, the first approach was used in the determination of the purging times of the methane in the headings studied.

Fig. 4 - 47 Profile of Tracer Gas Decay at Heading #9 Showing the Effects of Dilution by the Auxiliary Ventilation System

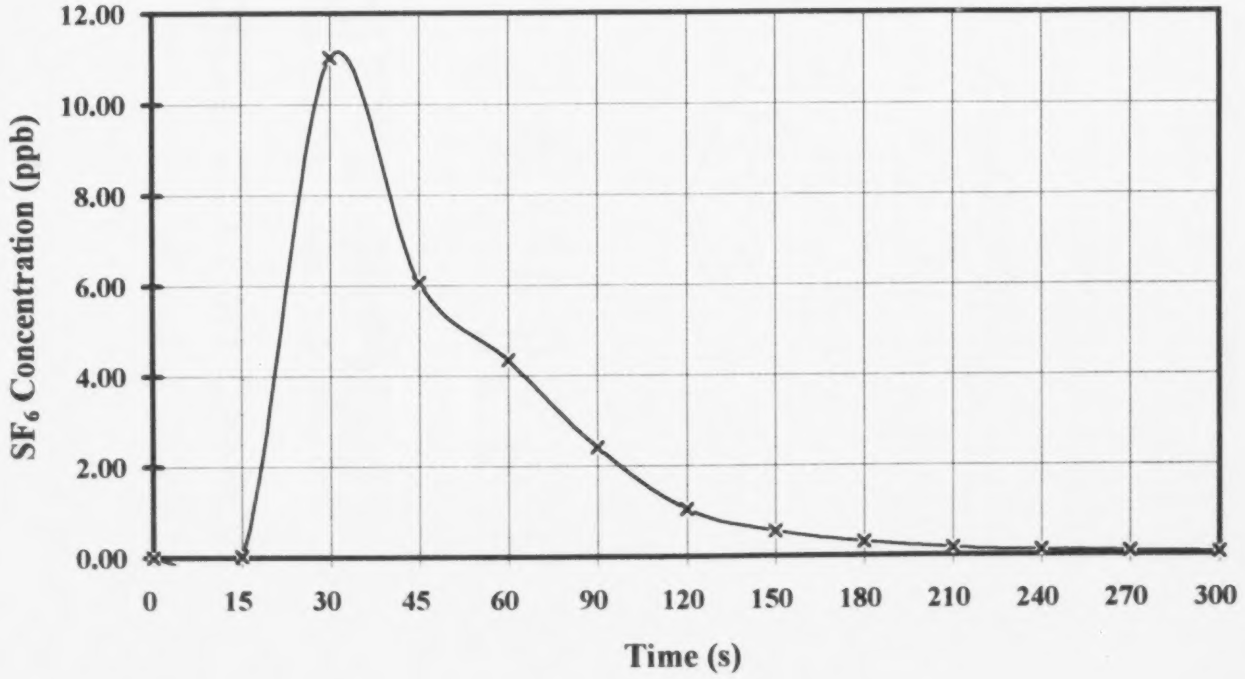


Fig. 4 - 48 Profile of Tracer Decay at Heading #10 Showing the Effect of Dilution by the Auxiliary Ventilation System

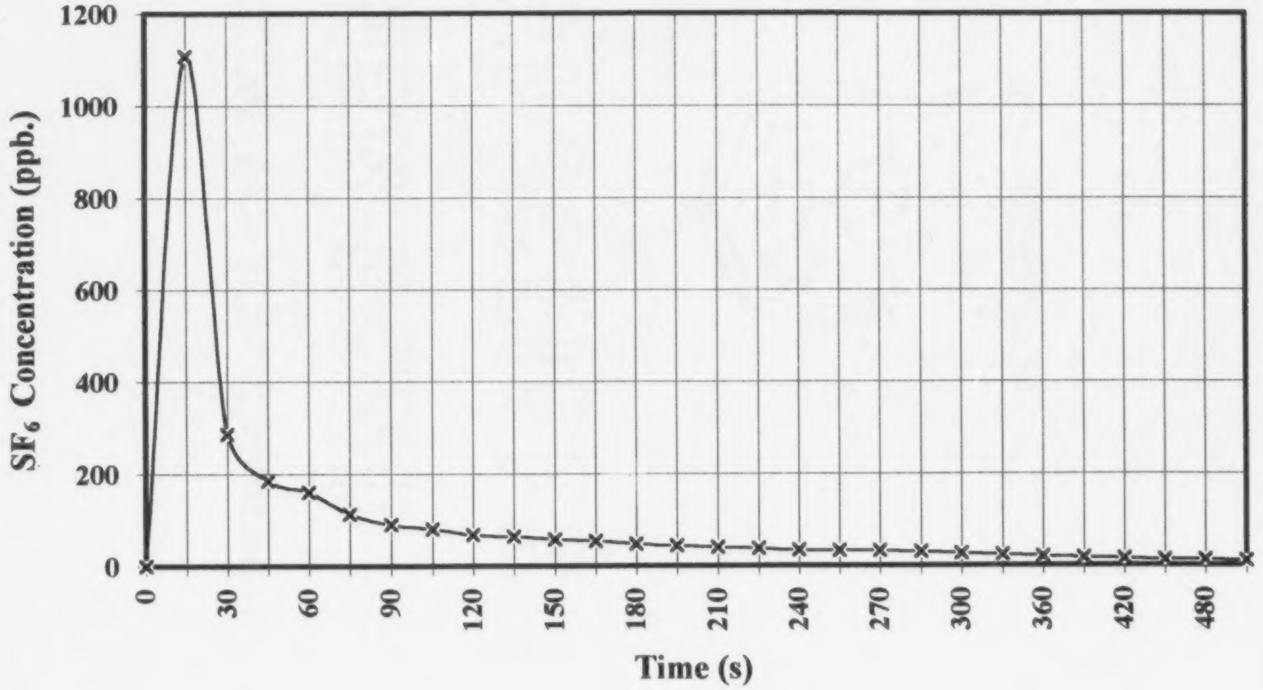


Fig. 4 - 49 Profile of Decay of Tracer Gas at Heading #11 showing the Effect of Dilution by the Auxiliary Ventilation System

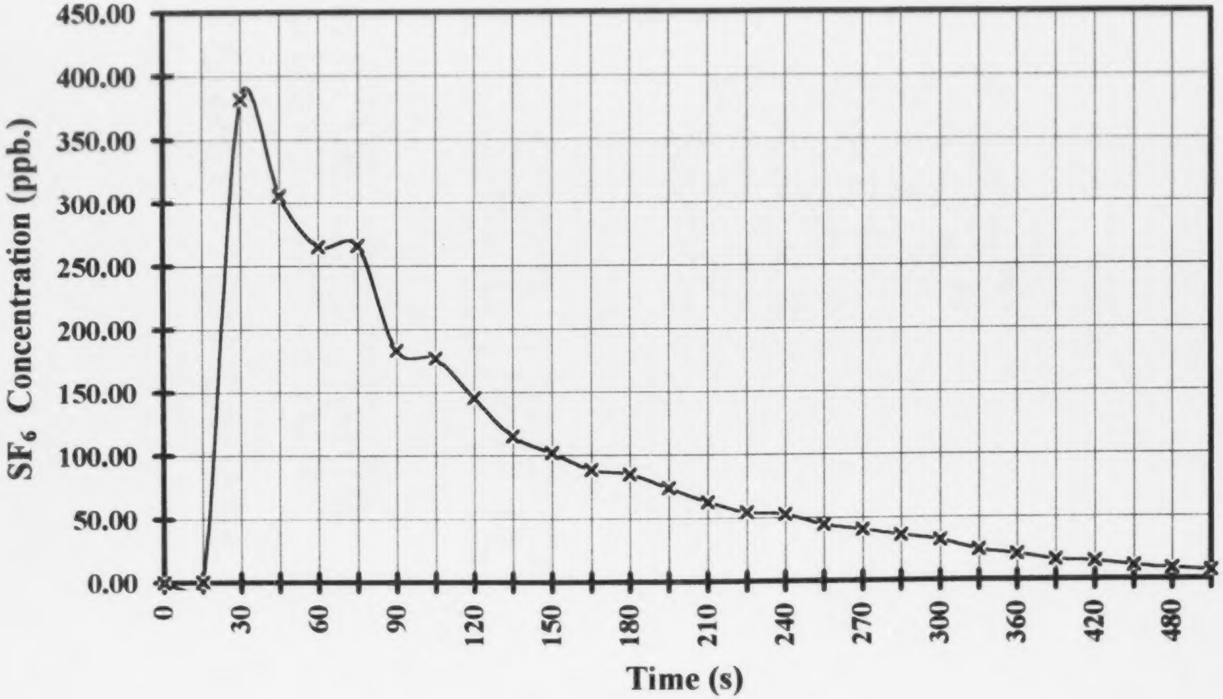


Fig. 4 - 50 Natural Log of Tracer Gas Decay Profile at Heading #9

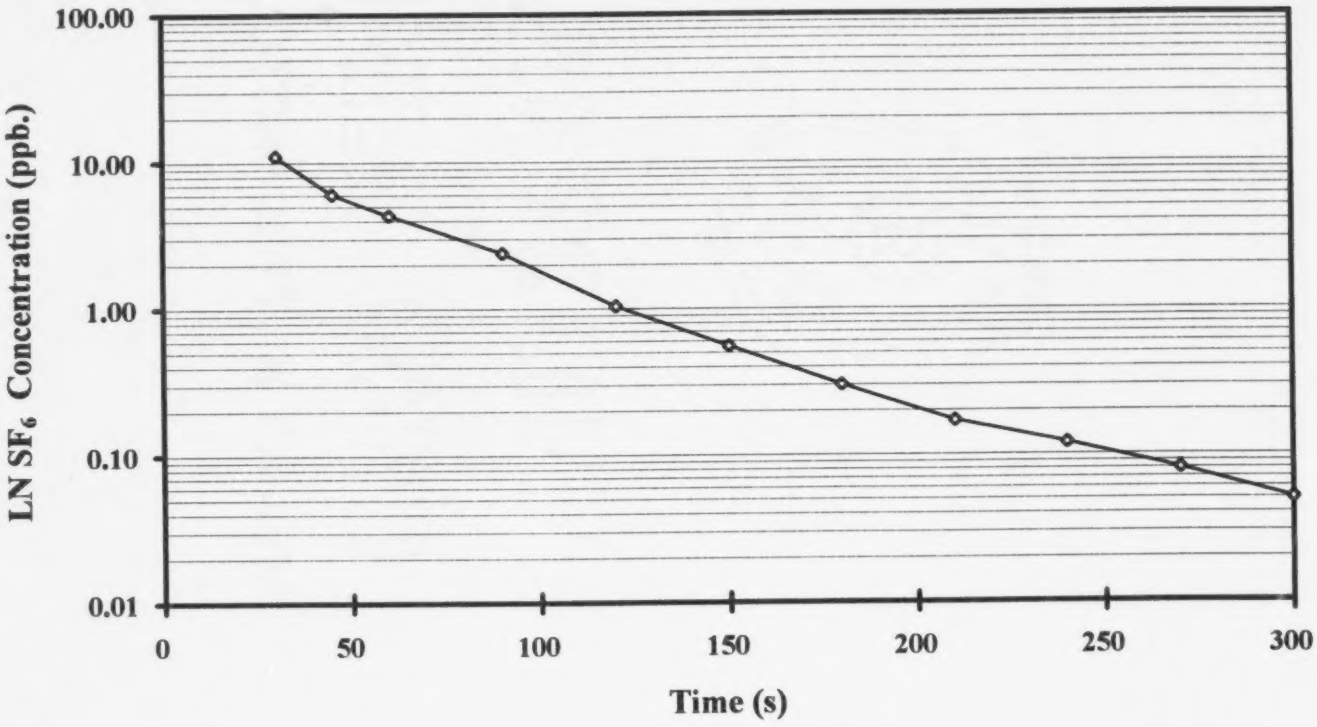


Fig. 4 - 51 Natural Log of Tracer Gas Decay Profile at Heading #10

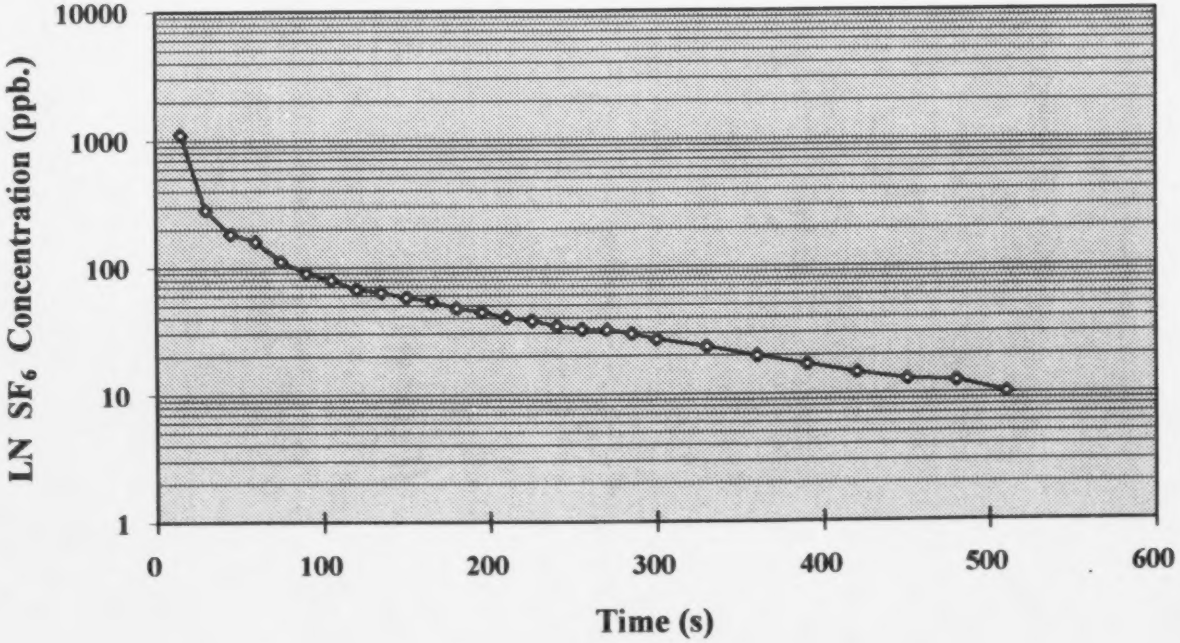
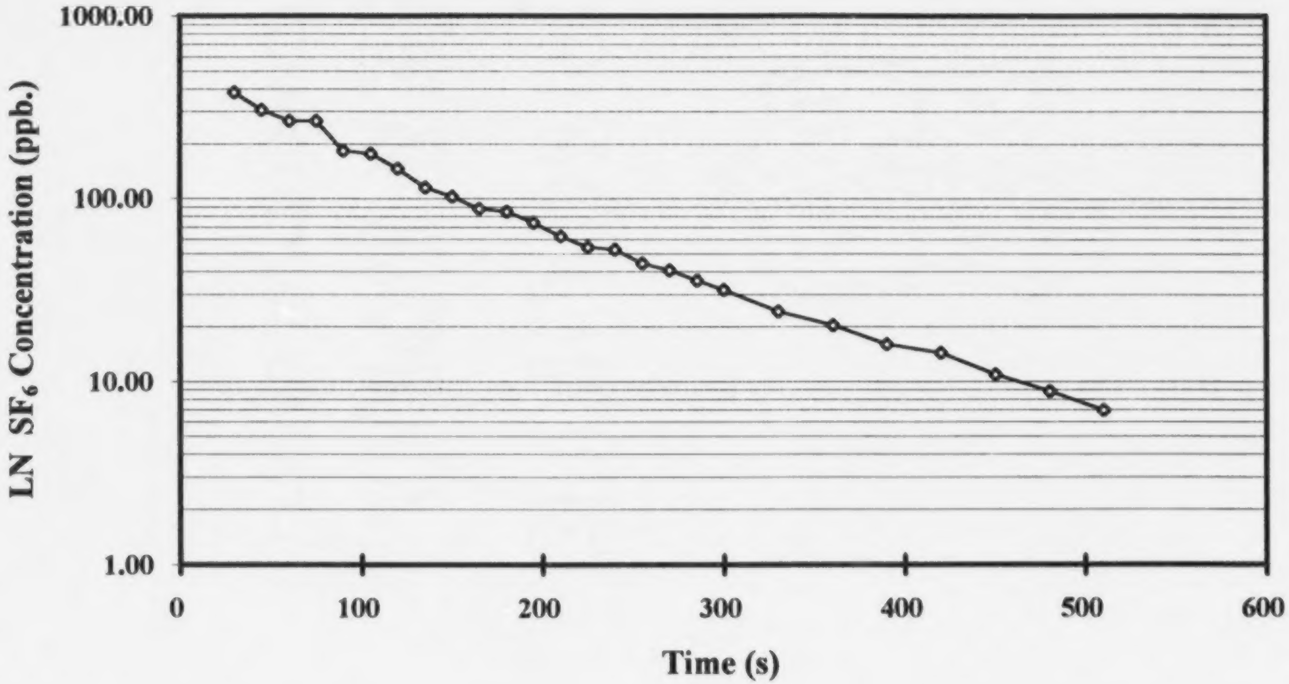


Fig. 4 - 52 Natural Log Plot of Tracer Gas Decay Profile at Heading #11



The gradients of the log concentration-time plots (λ) in Figs. 4 - 50 to 4 - 52 were found and plugged, together with the methane concentrations at the face and in the return air, into equation (4 - 28) and the purging times of the methane gas within the control volumes in the headings were determined. As an example, the gradient of the log concentration-time plot in Fig. 4 - 50 is about 0.0138, the average concentration of the methane gas in the return air (C_1) in Heading #9 was 0.26% by volume (Appendix D - 11) and the concentration of methane emanating from the strata (C_0) assumed to be 100%. Putting these values into equation (4 - 28) the following was obtained:

$$t = \frac{1}{0.0138} \ln\left(\frac{1}{0.026}\right)$$

$$= 264.33 \text{ s (4.41 minutes).}$$

In the same way the purging times of the methane at Headings 10 and 11 were also calculated to be 7.61 and 4.66 minutes respectively.

Assuming that the decay rate of the SF_6 simulates that of methane, the auxiliary ventilation systems in Headings 9 to 11 effectively dispersed and diluted any pockets of SF_6 concentration at the face to negligible levels in 4.41, 7.61 and 4.66 minutes respectively. From Graham's Law of Diffusion of gases (refer to equation 2 - 13), methane gas (s. g. = 0.55), which is much lighter, is expected to diffuse at a faster rate (about 3 times faster) than SF_6 (specific gravity of 5.11 relative to air). Table 4 - 6 shows the average purging times obtained from the empirical relations under Conditions 1 and 2 in Section 4.3.1 and those obtained from the tracer gas decay tests in Heading Nos. 9 to 11.

Comparing the purging times obtained from the tracer gas tests with those obtained from the empirical calculations, it can be observed that the raw tracer gas test values correlate much better with the values obtained under Condition 1 *(which involved the assumption that the methane emanating from the strata is pure in concentration by volume and it is diluted by the auxiliary ventilation system within the control volume to the return air concentration which was taken as that registered by the monitor in the return air)* than with those under Condition 2.

Table 4 - 6 Comparison of Average Purging Times from Empirical Calculations with those from Tracer Gas Tests.

	Empirical Calculations		Tracer Gas (SF_6) Test	
Heading No.	Condition 1 Time (min.)	Condition 2 Time (min.)	Time (min.)	Adjusted for Methane Diffusion rate (min.)
9	3.84	1.92	4.41	1.39
10	7.90	3.09	7.61	2.40
11	4.24	1.46	4.66	1.47

However when adjusted for the faster diffusion rate of methane relative to air, the adjusted values correlate well with those in Condition 2 (See columns 3 and 5 in Table 4 - 6). Due to the turbulence that usually exist in the airflow within the headings, the gases are thoroughly mixed together and thus the specific gravity of the mine air varies from 0.55 to 1.53 (*often close to 1.0*) [32]. It is therefore reasonable to take the close correlation between the raw values of purging times obtained from the SF_6 gas as more representative of the actual purging situation than the adjusted values.

The following observations may be made from the results of the tests on the effects of dilution on the decay rate of tracer gas in the three headings in this study:

1. The tests on the decay rate of SF_6 in a heading may be safely and reliably used to estimate the purging times of methane gas in development headings.
2. The tests confirm the theory (assumption) that the methane emanating from the strata is pure in concentration by volume.
3. The values from the tracer tests agree quite well with the results of purging times obtained from calculations using empirical relations in Section 4.3.1. This is so inspite of the numerous assumptions made in this work in the

calculations using empirical equations and the possible (unavoidable) experimental errors in the tests.

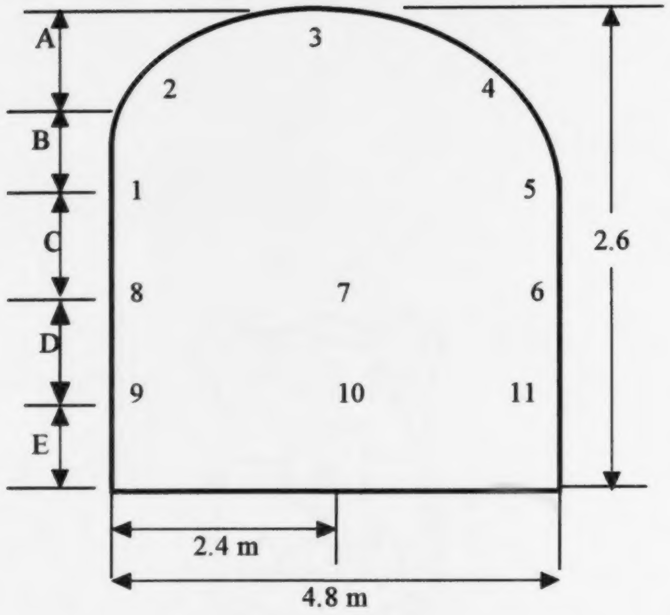
4. The auxiliary ventilation systems were quite effective in diluting and dispersing the methane concentrations to safe levels in less than 8 minutes within the control volumes in the three headings.

4.4.3 Methane Layering in Headings

In Section 2.3.6, the factors that determine methane layering in development headings were discussed. Tests were conducted within the control volumes in the headings during this work to determine whether there were any methane gas accumulations and stratified layers in the development headings studied and the areas where they were likely to occur.

The tests were conducted using handheld methanometers attached to probes. Small suction pumps were attached to the methanometers to draw the ambient air through the probe into the methanometers. Readings were taken within 1 cm from the roof and sides every 10 m along the drive starting from the face. Test positions were the roof, the floor and mid-point samples (left hand side, right hand side and center) as well as the general body sample. Fig. 4 - 53 shows the cross-section of a typical development heading in which the numbers indicate the test positions. Table 4 - 7 shows sample readings made at Heading # 10. The general body methane concentrations averaged 0.3%.

From volumetric flow measurements done in Heading #10, the air velocity at the face and at 10 m from the face were 0.15 and 0.28 m/s respectively. The heading was 4.8 m wide and 2.6 m high. The average methane emission rate calculated for Heading #10 (See Appendix E) was 1.7×10^{-3} m^3/s. Substituting these values into equation (2 - 14), the Methane Layering Number (N_l) at the face and at 10 m from the face are 1.2 and 2.2 respectively. These layering numbers in Heading #10 are far below the average value of 5 required to indicate the absence of layering. This means that layering is likely to occur in the heading.



A = 0.4 m
B = 0.45 m
C = 0.45 m
D = 1.2 m
E = 0.10 m

(Not To Scale)

Fig. 4 - 53 Cross-Section of a Typical Development Heading Showing Positions of Measurements for Methane Layering.

Furthermore, from Table 4 - 7, it is clear from the methane concentrations that there was some likelihood of methane layering in Heading #10 as the average concentrations of methane in the sections near the roof (positions 2 to 4) was 0.4%. While this value is not appreciably higher than the general body methane concentration of 0.3%, it does indicate the possibility of methane layering. However, it must be emphasized that detection of methane layering requires more sophisticated instruments for probing areas closer to the roofs than were available for use in this work. The tests done in this study may be taken only as an indication and methane layering in the headings was not detected by the available instrumentation. This area requires more detailed investigation in the future.

Table 4 - 7 Results of Tests On Methane Layering at Heading #10

Distance from Face.	0m	10 m	20 m	30 m	40 m	50m	60 m
Position # 1	0.4	0.3	0.4	0.4	0.3	0.2	0.2
Position # 2	0.5	0.4	0.4	0.5	0.4	0.3	0.2
Position # 3	0.4	0.5	0.4	0.4	0.4	0.5	0.3
Position # 4	0.4	0.3	0.5	0.4	0.3	0.3	0.3
Position # 5	0.3	0.3	0.4	0.2	0.3	0.4	0.2
Position # 6	0.3	0.2	0.3	0.3	0.3	0.4	0.2
Position # 7	0.6	0.4	0.5	0.5	0.4	0.3	0.2
Position # 8	0.3	0.4	0.4	0.3	0.3	0.2	0.2
Position # 9	0.2	0.3	0.3	0.2	0.3	0.2	0.2
Position # 10	0.3	0.2	0.2	0.3	0.3	0.2	0.2
Position # 11	0.3	0.3	0.2	0.3	0.2	0.2	0.2

Chapter Five

OBSERVATIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 OBSERVATIONS

From the tests, analysis and discussions reported in preceding sections, the following observations may be made:

1. The predominant auxiliary ventilation method employed by the mines studied in North America is primary forcing system with a secondary exhaust overlap.
2. Methane concentrations recorded by methane monitors at the face were about 80% higher than those recorded at about 60 m outbye in the return air in headings.
3. Face methane concentrations varied within wider limits than those in the return air.
4. The methane concentrations within the heading (*particularly those at the face*) were either abnormally high or showed gradually increasing trends during the shift when there was a problem with the auxiliary ventilation system in the heading (such as a break in the intake ducting of the auxiliary ventilation system, duct discharge end being too far from the face, etc.).
5. Differences between the methane concentrations at the face and in the return are a function of the efficiencies of the auxiliary ventilation system and the methane emission rates.
6. Average methane concentrations at the face and in the return air were less than 0.4% when the distance from the discharge end of the intake ducting to the face was less than 12 m.

7. The dominant drivers of the system in auxiliary ventilation systems *(arranged in order of importance)*, were distance from discharge end of ducting to the face, fan capacity, diameter and condition of the ventilation ducting. From the analysis, it was observed that generally auxiliary ventilation systems in which the discharge end of the intake ducting was in excess of 10 m had low system efficiencies and longer purging times to disperse and dilute the methane concentration to safe levels.

8. Tracer gas based techniques employed in assessing the performance parameters (such as volume flow rates and static pressure losses through ductings, methane concentration decay rates in headings, etc.), gave quick and reliable results in this work and collaborated the results of traditional anemometric surveys as well as those from empirical calculations. For example, the purging times for methane gas in development roadways calculated from empirical relations correlated well with those obtained from tracer gas tests within some selected headings. Purging times were less than 8 minutes in all the headings studied.

9. Tracer gas tests show that the methane emanating from the coal seams and surrounding strata is pure (100%) in concentration by volume.

10. Tracer gas tests on auxiliary ventilation systems, such as the flume tests, are superior to traditional methods of auxiliary ventilation surveys and it is possible to quantify the amount of leakage, the volume flow rates through sections of the auxiliary ventilation ducting, pressure losses, etc.

11. The efficiencies of the auxiliary ventilation systems studied had forcing system efficiencies ranging from 48.87% to 96.61% while the overall system efficiencies varied from 6.04% to 58.18%.

12. The average quantities of fresh air required to disperse, dilute and remove methane concentrations within set levels under Conditions 1 and 2 within one minute varied from a minimum of 7.35 m^3/s in Heading #9 (Condition 2) to 27.97 m^3/s in Heading #10 (Condition 1).

13. The efficiencies of the auxiliary ventilation systems under those conditions varied from 12.83 to 138.75%.

14. Tests for methane layering in headings indicated the likelihood of layering. The layering numbers calculated averaged 2.

5.2 CONCLUSIONS

From the analysis and observations made in this study it can be concluded that:

1. The substantially higher concentrations of methane gas recorded at the face compared with the return (outbye) air confirm the theory that a larger portion of the methane emitted from the coal seams and strata within the heading takes place at the face cutting area alone.

2. The higher methane concentrations recorded during cutting periods of coal than in roofbolting and other operations also confirms the theory that communition of coal increases the liberation rate of methane gas into mine workings.

3. Narrow differences between the methane concentrations at the face and return air and increasing trends in the methane concentration during a shift are indicators of a general problem with the auxiliary ventilation systems.

4. Distances from the discharge end of the primary intake ducting to the face is a stronger driver of auxiliary ventilation system performance than the other parameters like fan capacity, ducting diameter, length and condition, etc. Distances from the discharge end of the primary intake ducting to the face not exceeding 10 m, will generally ensure safe levels of methane concentration within the heading (≤ 0.4%), faster purging rates of the methane at the face (≤ 8 min.) and efficiencies of the forcing and overall auxiliary ventilation systems in excess of 45%.

5. Tracer gas based techniques in auxiliary ventilation surveys gave quick, reliable, accurate and collaborative results to other tests and calculations done in this study.

6. In empirical calculations on methane emission rates, dilution requirements, purging times of contaminants, etc., in auxiliary ventilation surveys, it is reasonable to assume that the methane concentration emanating from the strata and coal seams is pure (100%) in concentration by volume.

7. The forcing efficiencies of the auxiliary systems in the headings studied ranged from good to excellent while the overall system efficiencies varied from poor to good.

8. Required amounts of fresh air presently supplied to headings studied ranged from 12 to 26% of the quantities required to purge methane concentrations to safe levels within one minute under Condition 1 and 32 to 139% under Condition 2.

9. Most of the auxiliary ventilation systems are capable of controlling the methane concentrations within statutory levels but may not be able to cope with large and unusual methane makes in the headings.

10. The low layering numbers calculated (≈ 2) indicated that layering was likely to occur in the headings studied.

5.3 RECOMMENDATIONS

From the foregoing analysis, observations and conclusions, the following recommendations are made:

a) The primary forcing system with a secondary exhaust auxiliary ventilation system presently being employed in operating mines be maintained as these meet the ventilation requirements in the dispersal, dilution and safe removal of methane gas in the headings studied.

b) That the discharge end of the intake ductings be, as much as practicable, kept within 10 m from the working face to ensure that at least 45% of the intake air reaches the face for methane dispersal and dilution.

c) Tracer gas based techniques be employed in auxiliary ventilation surveys as they give faster, more accurate and reliable results than traditional methods of auxiliary ventilation surveys. Besides the results obtained from such surveys may easily be used to quickly locate and rectify problem areas in the auxiliary ventilation system.

d) Mine managements should strive to maintain the efficiencies of the overall auxiliary ventilation systems above 45% to ensure safe methane concentrations in the roadways.

e) Funding be provided for studies into methane gas layering in the headings as the present instruments are not capable of detecting very thin layers of methane near the roof and sides of the headings.

f) Finally, there is a great opportunity for co-operation between industry and research institutions such as the Universities in researching into and finding solutions to most of the ventilation, safety and health problems encountered in mine environments underground.

REFERENCES

1. Hartman, H. L. (1982), Mine Ventilation and Airconditioning, 2nd ed., *A-Wiley Interscience Publication*, 785pp.
2. Curl, S. J (1978), Methane Prediction In Coal Mines, *Report Number ICTS/TR 04, December 1978, London, IEA Coal Research*, 78pp.
3. Kissell, F. N. (1992), Dust and Gas Control, Ch. 12 of SME Mining Engineering Handbook, 2nd ed., H. L. Hartman, sen. ed., *Society of Mining, Metallurgical, and Exploration, Inc., Port City Press, Baltimore*, pp. 1004 - 1005
4. Vutukuri, V. S. and Lama R. D. (1986), Environmental Engineering in Mines, *Cambridge University Press, London*, pp. 3 - 161.
5. Anon. (1980), Code of Federal Regulations, Title 30, Mineral Resources, *U. S. Government Printing Office, Washington, D. C.*, July 1.
6. Greig, J. D. (1982), Gases Encountered in Mines, Ch. 26 of Environmental Engineering in South African Mines, J. Burrows, sen. ed., pp. 713 - 739.
7. Anon. (1980), Firedamp Drainage, Handbook of the Coal Mining Industry in the European Community, *Verlag Gluckauf GmbH, Essen*, 415pp.
8. Murray, K. D. (1990), Coal Bed Methane: Natural Gas Resources from Coal Seams, *Proceedings of Coal Bed Methane in Alberta - What's It all About?* pp. 1 - 12
9. Roberts, A. (1960), Mine Ventilation, *Cleaver-Hume Press, Ltd., London*, 355pp.
10. Edwards, J. S., Whittaker, B. N. and Durucan, S. (1988), Methane Hazards in Tunneling Operations, *Fifth International Symposium, Tunneling '88, Institution of Mining Engineers*, pp. 97 - 110.
11. Meissner, F. F. (1984), Cretaceous and Lower Tertiary Coals as Sources for Gas accumulations in Rocky Mountain area, in *Hydrocarbon Source Rocks of the Greater Rocky Mountain, J Woodward, F. F. Meissner and J. L. Clayton, eds.: Rocky Mountain Association of Geologists, Denver, CO*, pp. 401 - 431

12. Feng, K. K. and Augsten R. (1980), The Direct Method of Determining Methane Content of Cardinal River Coals, *Canada Center for Mineral and Energy Technology*, 21pp.

13. Konda, B. (1985), A Detailed Review and Evaluation of Methane Prediction Techniques and Their Applicability to Canadian Coal Mines, *Canada Center for Mineral and Energy Technology, Energy, Mines and Resources, Canada, Report No. 85 - 514*, pp. 1- 1 to 6 - 3.

14. Rabia, H. (1988), Mine Environmental Engineering, *Entrac Software, Newcastle Upon Tyne*, pp. 1 - 65.

15. Dunmore, R. (1981), Prediction of Emission from Longwall Faces, *The Mining Engineer (Feb. 1981)*, pp. 565 - 572.

16. Proudlock, P. J. (1990), An Overview of Albertan and Canadian Demethanation Experience, Technology Advances and Development Potential, *Proc. of Seminar of Coal Bed Methane in Alberta - What's it all about? Information Series No. 108, Calgary, Alberta Geol. Survey*, pp. 11 - 24.

17. Grau, R. H. III (1987), An Overview of Methane Liberations from U. S. Coal Mines in the Last 15 Years, *Proc. of the 3rd U. S. Mine Ventilation Symposium, Jan M. Mutmansky , ed., Society of Mining Engineers, Inc*, pp. 251 - 253.

18. Stripp, G. P. (1989), Current Research into the Problems of Methane Emissions in South African Collieries, *Journal of the Mine Ventilation Society of South Africa (Dec. 1989)*, pp 223 - 228.

19. Airey, E. M. (1971), The Theory of Gas Emission in Coal Mining Operations (Part 1), *National Coal Board, MRDE Internal Report No. 21.*

20. Anon. (1973), Noxious Gases Underground, A Handbook for Colliery Managers, *National Coal Board Scientific Control*, 39pp.

21. Kissell, F. N. (1989), Methane Control In Tunneling, *A Bureau of Mines Handbook, U. S. Department of Interior*, 16pp.

22. Burrows, J. (1982), Environmental Engineering in South African Mines, *The Mine Ventilation Society of South Africa, Johannesburg*, 987pp.

23. Floyd, C. B. (1983), A Manual on Mine Ventilation Practices, 2nd ed., *Floyd C. Bossard and Associates, Inc*, pp. 38 - 48.

24. Anon. (1978), Ventilation for Dust Control, National Coal Board, 24pp.

25. Anon. (1981), Ventilation in Coal Mines, A Handbook for Colliery Ventilation Officers, *National Coal Board, London*, 156pp.

26. Dalzell, R. W. (1966), Face Ventilation in Underground Bituminous Coal Mines, Performance Characteristics of Jute Line Brattice, *Bureau of Mines Report of Investigation (RI 6725)*, 31pp.

27. Hartman, H. L. (1961), Mine Ventilation and Airconditioning, *The Ronald Press Company, New York*, 390pp.

28. Anon. (1986), Auxiliary Ventilation Handbook, *Cape Brenton Development Corporation, Human Resources Division, Safety and Training Department, TM 18 - 10/86*, 60pp.

29. Barker, A. H. and Highton, W. (1981), Auxiliary Ventilation in its Wider Aspects, *The Mining Engineer*, Feb. 1981, pp. 573 - 581.

30. Simode, E. (1980), Auxiliary Ventilation Lines over Long Distances Using Several Fans arranged in Series, *Information Symposium, Methane Climate, Ventilation in Coal Mines of the European Communities, Luxemburg, Vol. 1, Colliery Guardian, Redhill, Surrey*, pp. 500 - 518.

31. Klinowski, G. W. and Kennedy, D. J. (1989), Tracer Gas Based Evaluation of the Auxiliary Ventilation Systems, *Proc. of the 4th U. S. Mine Ventilation Symposium, Berkeley, California*, pp. 123 - 127

32. Hargraves, A. J. (1983), Source and Extent of Mine Atmosphere Contaminants, *Proc. of the Symposium on Ventilation of Coal Mines, Australasian Institute of Mining and Metallurgy*, pp. 3 -1 to 3 -2.

33. Raybould, W. E. and Hughes, A. J. (1960), The Rapid Determination of the Explosibility of Mine Fire Gases, *The Mining Engineer*, pp. 37 - 53.

34. Wala, A. M. and Kim, J. K. (1985), Simulation of Unsteady State of airflow and Methane Concentration Processes in Mine Ventilation Systems caused by

Disturbances in Main Fan Operation, *Proc. of Second U. S. Mine Ventilation Symposium, Ed. P. Mousset-Jones, Reno, Nevada, Balkema*, pp. 85 - 93.

35. Hemeon, W. C. L. (1963), Plant and Process Ventilation, *2nd. ed., Industrial Press, New York*, p.121

36. Tsay, F., Palton, S. B. and Sanford, R. L. (1990), Prediction of Gas Emission in the Working Face Using Coalbed Methane Modeling, *Proc. of the Eighth Annual Workshop Generic Mineral Technology Center Mine System Design and Ground Control, Reno, Nevada*, pp. 173 - 180.

37. Kissell, F. N., Ruggieri, S. and Volkweim, J. (1986), Coal Mine Face Ignitions and the Methane Monitor, *Journal of the Mine Ventilation Society of South Africa*, pp. 49 - 54.

38. Klinowski, W. G. and Kennedy, D. (1991), Tracer gas Techniques Used in Mine Ventilation, *Proc. of the 5th U. S. Mine Ventilation Symposium, Morgantown, WV, Society of Mining, Metallurgy and petroleum, Inc., W, J. Wang, sen ed.*, pp. 662 - 666.

39. Gardiner, L. R. and Van der Linde, A. (1989), Scope and Appliaction of a New Tracer Gas Facility for Industry, *Journal of the Mine Ventilation Society of South Africa*, pp. 2 - 9.

40. Klinowski, W. G. and Kennedy, D. J. (1987), Resolving Complex Mine Ventilation Problems with Multiple Tracer Gases, *Proc. of the 3rd U. S. Mine Ventilation Symposium, Society of Mining, Metallurgy and Petroleum, Inc.*, pp. 213 - 218.

41. Kennedy, D. J. (1987), An Analytical method for Determining Trace Levels of Sulfur Hexafluoride and Bromotrifluoromethane and Dichlorodifluoromethane in Mine Air Samples, *Division Report CRL 87-86 (TR), Energy, Mines and Resources Canada, Sydney, Nova Scotia*, 9pp.

APPENDIX A

SUMMARY OF RESULTS FROM QUESTIONNAIRES

APPENDIX A

A - 1

SUMMARY OF RESULTS FROM QUESTIONNAIRES

Mine	Mine No. 1	Mine No. 2	Mine No. 3	Mine No. 4	Mine No. 5	Mine No. 6	Mine No. 7	Mine No. 8
Annual Production (tonnes)	3200000	2200000	2115371	5000000	750000	1251818	2883000	1300000
Work Schedule								
Days/yr	230	240	242	244	350	242	235	235
Days/week	5	5	5	5	7	5	5	5
Shifts/day	3	2	2	3	3	2	3	3
Hours/shift	8	8	8 or 9	8	8	8	8	8
Thickness Seam	1.22 - 1.65	1.63	1.37	1.52 - 2.44	3.05	1.52	2.4	2.13
Depth	168	244 - 307	67	193 - 305	5.72 - 121.9	107	700	305
Mining Method	L/w	R&P	R&P	R&P	R&P	R&P	L/w Retreat	L/w retreat
No. Production Units	2 Miner & 1 L/w	(CM=3 & 1 Conv	4	9	3	2	2	1
Avg. Shift Production/unit	909 - Miner	1600 - 3 CMs	1187	11091	682	1091	2100	1600
Avg. Shift Production/unit	3636 L/w	1160 - Conv.						
Average Crew Size/prod.unit	11 - Miner	Miner = 10	9	13	7	11	12	15
Average Crew Size/prod.unit	7 - L/w	Conv. = 13						
Methane Emission Rates								
Average (m^3/tonne) - Miner	3.35		0.6	5.02	0.99			1.5
Maximum (m^3/tonne) - Miner	6.69			6.28				
Normal Vent. flow in Prod. U	14.16	In - 130.50		18.88	28.32			15
		Out - 157.72						
% CH_4 in Gen. Body of Return	0.6	0.5	trace	0.2	0.1			0.5
verage (m^3/tonne) - L/w	0.85							
aximum (m^3/tonne) - L/w	1.7							
ormal Vent. flow in Prod. Uni	23.6							
% CH_4 in Gen. Body of Return	0.5							

APPENDIX A

A - 2

SUMMARY OF RESULTS FROM QUESTIONNAIRES

Mine	**Mine No. 1**	**Mine No. 2**	**Mine No. 3**	**Mine No. 4**	**Mine No. 5**	**Mine No. 6**	**Mine No. 7**	**Mine No. 8**
Type and No. of Main Fan	2 Exhaust	1 Joy Exh (1 backup	1 Exhaust	4 Exhaust	4 Exhaust	1 Exhaust	1 Exhausting	Exhaust
Location	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Size(s), (m)	2.97	2.13	2.74	2.44	, 1.06,1.37 &	2.44		
Horsepower (HP)	1250 (800 Backup)	750	1500	1250	200, 60, & 100	400		548
Mine Head (ins.WG,Pa)	0 - 11 (0 - 8 Backup)	8	11	10 to 11	1.75, 0.3 & 0.1	3.1		5.2
Capacity (m^3/s)	283 (236 Backup)		165.18		82.59 & 49.55	151.02		160
Type of Main Vent. fans	Vane Axial	Vane Axial	Vane Axial	Vane Axial	Vane axial	Vane axial	Centrigugal-BB	Centrifugal-BB
No. of Intake Main Entries	3	7	2	2 to 8	2	5	3	2
Height (m)	1.52	1.52	1.37	1.52 - 2.44	2.74	1.52	3.66	3.66
Width (m)	5.18	5.49 - 6.1	6.1	5.49 - 6.1	6.1	6.71	5.49	4.88
Area (m^2)	7.90	8.36 - 9.29	8.36	8.34 - 14.88	16.73	10.20	16.82	17.85
Velocity (m/s)	variable		2.82		Variable	0.84		
Quantity (m^3/s)	47.2 - 94.4		23.9			69.85		
No. of Return Main Entries	3	7	3	2 to 8	1	5	2	1
Height (m)	1.52	1.52	1.37	1.52 - 2.44	3.05	1.52	3.66	3.66
Width (m)	5.18	5.49 - 6.1	6.1	5.49 - 6.1	6.1	6.71	5.49	4.88
Area (m^2)	7.9	8.36 - 9.29	23.9	8.34 - 14.88	18.61	10.19	16.82	17.85
Velocity (m/s)	variable		3.76	variable	Variable			
Quantity (m^3/s)	47.2 - 141.6		31.62					
Mine Development - Main								
Number	8	14	7	7 to 14	3	8	5	3
Width (m)	5.18	4.88 - 5.49	6.1	5.49 - 6.1	6.1	6.71	5.49	
Height (m)	1.52	1.63	1.37	1.52 - 2.44	3.05	1.4	3.66	
Area (m^2)	7.90	7.95 - 8.95	8.36	8.34 - 14.88	18.61	9.39	20.09	

APPENDIX A

A - 3

SUMMARY OF RESULTS FROM QUESTIONNAIRES

Mine	**Mine No. 1**	**Mine No. 2**	**Mine No. 3**	**Mine No. 4**	**Mine No. 5**	**Mine No. 6**	**Mine No. 7**	**Mine No. 8**
Mine Development - Panel								
Number	4	5 to 7	6	5 to 8		8 to 10	4	2 (@ a time)
Width (m)	5.49	4.88 - 6.1	6.1	5.49 - 6.71		6.71	4.8	4.28 & 4.88
Height (m)	1.52	1.63	1.37	1.52 - 2.44		1.4	2.6	2.03 & 2.18
Area (m^2)	8.36	7.95 - 9.93	8.36	8.34 - 16.37		9.39	12.48	8.69 &10.66
Mine Development -District								
Number		7		7 to 8	5		7	
Width (m)		4.88 - 5.49		5.49 - 6.1	6.1		4.8	
Height (m)		1.63		1.52 - 2.44	3.05		2.6	
Area (m^2)		7.95 - 8.95		8.34 - 14.88	8.36		12.48	
Drivage Methods	iner & 3 RAM ca	2 Cms	Ms& shuttle	8	M & shuttle c	ers & 5 RA	Roadheaders	Roadheaders
Model(s)	oy 14 CM14 Mine	Joy 14CM15 -11B	14 CM9-11	14 CM15	Joy 12/11CM	ers & 5 RA	osco MK#B (2	Dosco MKIIA (1)
	Jeffrey 4114	1 Conv. unit	Joy 21Sc	effrey RAM c	ttlecars = 105	oy 14XCM1	lpine AM-75 (3	Dosco MKIIB (2)
Advance/shift (m) - Main	Miner Unit							
Average (m)	60.96	91.74	78.33	54.86		61	2	2.29
Maximum (m)	91.44	121.92	130.45	76.2		85.34	4	2.74
ROM Coal Produced/shift -	909	CM = 1455	1187	1045	1129	1273	32	40
ROM Coal Produced/shift -	1364	CM = 2504	2073	2182	2194	1818	64	50
Advance/shift (m) - L/W	L/w	Conv.		District			Panel	Panel
Average (m)	3636	1054		Avg = 1045			5	6.1
Maximum (m)	5455	1909		Max. = 2182			10	6.1
ROM Coal Produced/shift - Avg.				Panel			80	100
ROM Coal Produced/shift - Max.				Avg. = 1364			160	135
				Max.= 2273				

APPENDIX A

A- 4

SUMMARY OF RESULTS FROM QUESTIONNAIRES

Mine	Mine No. 1	Mine No. 2	Mine No. 3	Mine No. 4	Mine No. 5	Mine No. 6	Mine No. 7	Mine No. 8
Auxiliary Ventilation - Types								
Main Drivages	Exhausting				Exhausting	F & Exh. Overlap		F & Exh. Overlap
District Drivages	Exhausting				Exhausting			
Panel Drivages	Exhausting					F & Exh. Overlap		F & Exh. Overlap
Line Brattice	In all	used in all	used in all		1.22 m from face			
Types of Auxiliary fans							Vane Axial	Vane axial
Types of Ducting							Rigid, Flexible	Rigid & Flexible
AUXILIARY VENT. SYSTEM PERFORMANCE								
Minimum Air Quantity (m^3/s)			4.25 Min.					
Minimum Air Velocity in Roadway (m/s)			1.88					
Methane Emission Rate in Heading(s) (m^3/s)			trace					
Avg. Methane Conc. in Return			trace				0.1	0.1
Distance from end of Vent Duct to face (m)		11.58 (max)					5 (max.)	5 (max.)
Avg. Heading Machine Cutting Rate/hr			148					
Max. Instantaneous Cutting Rate/hr			259					
GENERAL MINE ENVIRONMENTAL DATA								
Avg. Mine Air Temp. Summer (°C)	20	15.6	13.3	21.1			19	11
Avg. Mine Air Temp. Winter (°C)	16.7	15.6	13.3	15.6			10	8
Avg. Surface Air Temp. Summer (°C)	32.2		35 - 40.6	26.7			22	22
Avg. Surface Air Temp. Winter (°C)	4.4		0 - 7.2	4.4			-13	-11
Rel. Humidity Range	50 - 100		75	40 - 100			40 - 100	54 - 90

APPENDIX B

AUXILIARY VENTILATION SYSTEM EFFICIENCIES AT DIFFERENT HEADINGS

APPENDIX B

B - 1

DEVELOPMENT HEADING No. 1

	NOV. 93	DEC. 93	JAN. 94	FEB. 94	MAR. 94	APRIL. 94	MAY. 94	JUNE. 94	JULY/AUG. 94
Fan Type (forcing)	44.76 kW	44.76 kW	44.76 kW	22.38 kW	22.38 kW	22.38 kW	55.95 kW	55.95 kW	55.95 kW
Ducting Dia. (mm)	1070	1070	1070	1070	1070	1070	1070	1070	1070
Ducting Length (m)	590	590	590	590	590	590	590	590	594
Area of Ducting (m^2)	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Quantity to Fan (Q_{t1}, m^3/s)	32.20	17.70	13.30	13.00	9.90	11.50	25.70	38.10	25.10
Quantity through Fan (Q_f, m^3/s)	8.20	8.50	8.10	7.20	6.90	7.10	8.20	9.40	9.40
Quantity at Duct End (Q_i, m^3/s)	4.30	3.90	4.80	5.10	4.20	3.20	4.50	8.50	8.40
Duct distance from Face (m)	5	1	1	1	1	1	1	1	12
Quantity @ Face (Q_e, m^3/s)	4.10	3.86	4.76	5.05	4.16	3.17	4.46	8.42	4.74
Return CH_4 conc. (%)	0.15	0.20	0.10	0.25	0.20	0.20	0.10	0.05	0.10
Effic. of Forcing System (E_f, %)	52.44	45.88	59.26	70.83	60.87	45.07	54.88	90.43	89.36
Overall Effic. of System (E_o, %)	49.99	45.46	58.71	70.17	60.30	44.65	54.37	89.58	50.37

APPENDIX B							B - 2	
DEVELOPMENT HEADING No. 2								
	NOV. 93	DEC. 93	JAN. 94	MAR. 94	APRIL. 94	MAY. 94	JUNE. 94	JULY/AUG. 94
Fan Type (forcing)	55.95 kW	55.95 kW	55.95 kW	55.95 kW	55.95 kW	55.95 kW	55.95 kW	22.38 kW
Ducting Dia. (mm)	1070	1070	1070	1070	1070	1070	1070	1070
Ducting Length (m)	170	180	120	160	180	210	230	230
Quantity to Fan (m^3/s)	54.00	50.20	39.80	34.30	34.60	37.80	34.00	40.40
Quantity to Fan (Q_{t1}, m^3/s)	11.20	11.40	11.20	12.40	12.00	13.00	9.20	6.10
Quantity through Fan (Q_f, m^3/s)	9.10	[illegible]	9.20	9.70	9.50	11.50	7.80	5.20
Quantity at Duct End (Q_i, m^3/s)	19	24	29	24	18	21	10	24
Quantity @ Face (Q_e, m^3/s)	3.34	2.04	1.19	2.20	3.76	3.58	5.03	1.18
Fan Type (Exhausting)	7.46 kW	7.46 kW	7.46 kW	7.46 kW	7.46 kW	7.46 kW	Idle	Idle
Ducting Dia. (mm)	600	600	600	600	600	600	n/a	n/a
Ducting Length (m)	30	30	30	30	30	36	n/a	n/a
Quantity at Duct End (m^3/s)	3.00	2.80	3.40	3.10	3.10	3.50	n/a	n/a
Duct distance from Face (m)	2	2	2	1	1	2	n/a	n/a
Quantity @ Face (m^3/s)	0.21	0.20	0.24	0.28	0.28	0.25	n/a	n/a
Return CH_4 conc. (%)	n/a	0.10	0.20	0.10	0.10	0.10	0.05	0.10
Effic. of Forcing System (E_f, %)	81.25	78.95	82.14	78.23	79.17	88.46	84.78	85.25
Overall Effic. of System (E_o, %)	29.84	17.93	10.60	17.77	31.30	27.52	54.73	19.36

APPENDIX B

B - 3

DEVELOPMENT HEADING No. 10

	NOV. 93	DEC. 93	JAN. 94	FEB. 94	MAR. 94	APRIL. 94	MAY. 94	JUNE. 94
Fan Type (forcing)	Comp. Air	Comp. Air	Comp. Air	22.38 kW	44.76 kW	44.76 kW	x 44.76 k	2 x 44.76 kW
Ducting Dia. (mm)	600	600	600	900	1070	1070	1070	1070
Ducting Length (m)	30	44	44	180	300	540	950	1220
Quantity to Fan (Q_{t1}, m^3/s)	50.20	39.80	38.00	34.30	34.60	37.80	34.00	40.40
Quantity through Fan (Q_f, m^3/s)	4.00	3.30	3.00	5.90	10.40	10.20	7.10	8.20
Quantity at Duct End (Q_l, m^3/s)	3.90	3.20	2.80	5.00	9.00	6.40	5.60	6.40
Duct distance from Face (m)	5	4	7	26	13	15	13	16
Quantity @ Face (Q_e, m^3/s)	3.72	3.08	2.36	0.86	4.82	3.07	3.00	2.89
Fan Type (Exhausting)				37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW
Ducting Dia. (mm)	n/a	n/a	n/a	600	600	600	600	600
Ducting Length (m)	n/a	n/a	n/a	28	28	29	29	31
Quantity at Duct End (m^3/s)	n/a	n/a	n/a	3.80	3.80	4.70	4.30	4.40
Duct distance from Face (m)	n/a	n/a	n/a	1	1	1	1	1
Quantity @ Face (m^3/s)	n/a	n/a	n/a	0.266	0.266	0.329	0.301	0.308
Return CH_4 conc. (%)	0.05	0.1	0.10	0.10	0.20	0.25	0.25	0.30
Effic. of Forcing System (E_f, %)	97.50	96.97	93.33	84.75	86.54	62.75	78.87	78.05
Overall Effic. of System (E_o, %)	92.95	93.34	78.61	14.49	46.34	30.05	42.24	35.23

APPENDIX B										B - 4
	DEVELOPMENT HEADING #13						DEV. HEADING #14			
	JAN. 94	FEB. 94	MAR. 94	APR. 94	MAY. 94	JUNE. 94	MAY. 94	JUNE.94	JULY. 94	AUG.94
Fan Type (forcing)	22.38 k	22.38 kW	22.38 kW	22.38 kW	22.38 kW	22.38 kW	22.38 kW	22.38 kW	22.38 kW	22.38 kW
Ducting Dia. (mm)	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
Ducting Length (m)	15	80	110	120	190	320	110	190	230	240
Quantity to Fan (Q_{t1}, m^3/s)	21.10	23.30	29.60	29.40	30.10	29.80	13.60	13.90	13.20	13.20
Quantity through Fan (Q_f, m^3/s	8.60	8.60	8.10	7.90	7.80	7.20	8.40	8.20	7.50	7.20
Quantity at Duct End (Q_3, m^3/s	8.30	8.50	7.50	7.50	7.00	6.80	7.80	7.10	7.00	6.70
Duct distance from Face (m)	17	23	12	23	21	21	14	9	19	15
Quantity @ Face (Q_e, m^3/s)	3.51	2.17	4.23	1.91	2.18	2.12	3.96	5.05	2.57	3.21
Fan Type (Exhausting)	7.46 kW	7.46 kW	7.46 kW	7.46 kW	7.46 kW	7.46 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW
Ducting Dia. (mm)	600	600	600	600	600	600	600	600	600	600
Ducting Length (m)	30	30	30	30	30	30	89	74	150	165
Quantity at Duct End (m^3/s)	3.20	3.00	3.20	3.40	3.70	3.30	3.20	5.20	3.20	3.00
Duct distance from Face (m)	1	1	1	1	2	2	1	2	2	1
Quantity @ Face (m^3/s)	0.224	0.21	0.224	0.238	0.259	0.231	0.22	0.36	0.22	0.21
Return CH_4 conc. (%)	0.15	0.1	0.1	0.15	0.35	0.15	0.15	0.10	0.25	0.25
Effic. of Forcing System (E_f,	96.51	98.84	92.59	94.94	89.74	94.44	92.86	86.59	93.33	93.06
Overall Effic. of System (E_o, %	40.85	25.21	52.19	24.22	27.92	29.38	47.13	61.59	34.27	44.57

APPENDIX B						B - 5
DEVELOPMENT HEADING #11						
	FEB. 94	MAR. 94	APR. 94	MAY.94	JUNE.94	JULY/AUG. 94
Fan Type (forcing)	55.95 kW	55.95 kW	55.95 kW	55.95 kW	22.38 kW	55.95 kW
Ducting Dia. (mm)	1070	300	300	300	1070	1070
Ducting Length (m)	140	150	150	150	205	380
Quantity to Fan (Q_{t1}, m^3/s)	38.00	34.30	34.60	37.80	34.00	40.40
Quantity through Fan (Q_f, m^3/s)	13.00	12.40	12.00	13.00	5.70	7.00
Quantity at Duct End (Q_i, m^3/s)	11.90	1.40	1.40	1.00	4.70	6.20
Duct distance from Face (m)	13	4	4	4	11	14
Quantity @ Face (Q_e, m^3/s)	6.37	1.35	1.35	0.96	2.78	3.15
Fan Type (Exhausting)	7.46 kW	Idle	Idle	Idle	37.3 kW	37.3 kW
Ducting Dia. (mm)	600	n/a	n/a	n/a	600	600
Ducting Length (m)	26	n/a	n/a	n/a	28	28
Quantity at Duct End (m^3/s)	3.30	n/a	n/a	n/a	3.30	3.00
Duct distance from Face (m)	2	n/a	n/a	n/a	1	1
Quantity @ Face (m^3/s)	0.231	n/a	n/a	n/a	0.231	0.21
Return CH_4 conc. (%)	0.10	0.10	0.10	0.10	0.15	0.15
Effic. of Forcing System (E_f, %)	91.54	11.29	11.67	7.69	82.46	88.57
Overall Effic. of System (E_o, %)	49.02	10.87	11.23	7.40	48.78	44.95
n/a - Not Available						

APPENDIX B B - 6

DEVELOPMENT HEADING #8

	DEC. 93	JAN. 94	FEB. 94	MAR. 94	APR. 94	MAY.94	JUNE. 94	JULY 94	AUG. 94
Fan Type (forcing)	2 x 44.76 kW	2 x 44.76 kW	2 x 44.76 kW	2 x 44.76 kW	2 x 44.76 kW	2 x 44.76 kW	2 x 44.76 kW	2 x 44.76 kW	2 x 44.76 kW
Ducting Dia. (mm)	1070	1070	1070	1070	1070	1070	1070	1070	1070
Ducting Length (m)	1470	1580	1900	1240	1360	1730	1970	2120	2240
Quantity to Fan (Q_{t1}, m^3/s)	32.00	22.70	21.40	18.80	19.40	19.60	19.40	21.40	21.40
Quantity through Fan (Q_f, m^3/s	11.30	10.00	11.10	7.10	8.20	7.10	6.80	6.40	6.30
Quantity at Duct End (Q_d, m^3/s	6.40	4.80	5.30	4.20	4.90	5.20	4.90	4.70	4.00
Duct distance from Face (m)	14	9	10	8	14	16	9	18	12
Quantity @ Face (Q_e, m^3/s)	3.25	3.41	3.42	3.26	2.49	2.35	3.49	1.86	2.25
Fan Type (Exhausting)	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW
Ducting Dia. (mm)	600	600	600	600	600	600	600	600	600
Ducting Length (m)	35	35	35	35	35	35	33	33	32
Quantity at Duct End (m^3/s)	3.00	3.10	3.00	3.20	3.40	3.00	3.20	3.00	3.10
Duct distance from Face (m)	1	1	1	1	1	1	1	1	1
Quantity @ Face (m^3/s)	0.21	0.22	0.21	0.22	0.24	0.21	0.22	0.21	0.22
Return CH_4 conc. (%)	0.1	0.2	0.2	0.4	0.5	0.3	0.35	0.4	0.25
Effic. of Forcing System (E_f,	56.64	48.00	47.75	59.15	59.76	73.24	72.06	73.44	63.49
Overall Effic. of System (E_o,	28.74	34.14	30.82	45.94	30.33	33.06	51.26	29.04	35.79

APPENDIX B								B - 7	
DEVELOPMENT HEADING #9									
	DEC. 93	JAN. 94	FEB. 94	MAR. 94	APR. 94	MAY. 94	JUNE. 94	JULY 94	AUG. 94
Fan Type (forcing)	22.38 kW	22.38 kW	22.38 kW	44.76 kW	44.76 kW	44.76 kW	2 x 44.76 kW	2 x 44.76 kW	2 x 44.76 kW
Ducting Dia. (mm)	1070	1070	1070	1070	1070	1070	1070	1070	1070
Ducting Length (m)	400	570	930	330	420	800	1150	1450	100
Quantity to Fan (Q_{t1}, m^3/s)	23.60	21.10	23.30	18.80	19.40	19.60	19.40	21.40	21.40
Quantity through Fan (Q_f, m^3/s	7.60	6.10	7.60	10.40	9.20	8.40	7.80	6.90	6.50
Quantity at Duct End (Q_i, m^3/s	5.60	4.70	4.50	7.90	4.80	6.30	5.50	4.80	4.30
Duct distance from Face (m)	18	5	6	17	18	12	14	14	10
Quantity @ Face (Q_e, m^3/s)	2.21	4.48	4.08	3.34	1.90	3.55	2.79	2.44	2.78
Fan Type (Exhausting)	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW
Ducting Dia. (mm)	600	600	600	600	600	600	600	600	600
Ducting Length (m)	30	30	30	30	30	30	32	30	30
Quantity at Duct End (m^3/s)	3.4	3	3.3	3.1	3	3	3.7	3.3	3.3
Duct distance from Face (m)	1	1	1	1	1	1	1	1	1
Quantity @ Face (m^3/s)	0.238	0.21	0.231	0.217	0.21	0.21	0.259	0.231	0.231
Return CH_4 conc. (%)	0.25	0.15	0.20	0.20	0.25	0.30	0.30	0.25	0.30
Effic. of Forcing System (E_f,	73.68	77.05	59.21	75.96	52.17	75.00	70.51	69.57	66.15
Overall Effic. of System (E_o, %	29.13	73.45	53.73	32.15	20.63	42.28	35.79	35.30	42.70

APPENDIX B					B - 8	
	DEV HDG #15	DEV. HEADING #16		DEV. HEADING #17		
	MAY.94	JUNE. 94	JULY/AUG.94	MAY. 94	JUNE. 94	JULY/AUG. 94
Fan Type (forcing)	22.38 kW	22.38 kW	22.38 kW	Comp. Air	Comp. Air	Comp. Air
Ducting Dia. (mm)	1070	1070	1070	600	600	600
Ducting Length (m)	140	80	90	14	19	52
Quantity to Fan (Q_{t1}, m^3/s)	25.10	20.80	21.10	6.50	5.10	5.00
Quantity through Fan (Q_f, m^3/s)	7.00	8.60	8.60	2.80	3.40	3.40
Quantity at Duct End (Q_i, m^3/s)	6.00	8.50	8.50	2.80	3.30	3.30
Duct distance from Face (m)	24	21	3	3	2	2
Quantity @ Face (Q_e, m^3/s)	1.36	2.64	8.26	2.72	3.24	3.24
Fan Type (Exhausting)	7.46 kW	37.3 kW	n/a	n/a	n/a	n/a
Ducting Dia. (mm)	600	600	n/a	n/a	n/a	n/a
Ducting Length (m)	29	28	n/a	n/a	n/a	n/a
Quantity at Duct End (m^3/s)	3.1	4.7	n/a	n/a	n/a	n/a
Duct distance from Face (m)	1	1	n/a	n/a	n/a	n/a
Quantity @ Face (m^3/s)	0.22	0.42	n/a	n/a	n/a	n/a
Return CH_4 conc. (%)	0.1	0.10	0.10	0.50	0.45	0.40
Effic. of Forcing System (E_f, %)	85.71	98.84	98.84	100.00	97.06	97.06
Overall Effic. of System (E_o, %)	19.47	30.75	96.07	97.20	95.24	95.24

APPENDIX B

B - 9

DEVELOPMENT HEADING #19

	DEC. '93	JAN '94	FEB. 94	MAR. 94	APR. 94	MAY. 94	JUNE.94	JULY/AUG. 94
Fan Type (forcing)	29.84 kW	29.84 kW	29.84 kW	29.84 kW	29.84 kW	29.84 kW	29.84 kW	29.84 kW
Ducting Dia. (mm)	914	914	914	914	914	914	914	914
Ducting Length (m)	244	244	335	351	366	366	366	244
Quantity to Fan (Q_{t1}, m^3/s)	15.29	14.44	13.45	16.1	19.82	13.97	14.35	11.75
Quantity through Fan (Q_f, m^3/s)	9.44	9.252	9.68	9.63	9.44	9.68	9.53	8.78
Quantity at Duct End (Q_i, m^3/s)	8.73	7.78	9.35	9.34	8.92	9.16	8.78	8.7
Duct distance from Face (m)	24.4	31.7	32.3	33.8	30.5	27.4	43	16.5
Quantity @ Face (Q_e, m^3/s)	1.16	0.41	0.47	0.47	0.59	0.92	0.44	3.12
Fan Type (Exhausting)	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW
Ducting Dia. (mm)	762	762	762	762	762	762	762	762
Ducting Length (m)	30.48	39.01	39.01	39.32	39.62	33.83	49.38	22.86
Quantity at Duct End (m^3/s)	7.08	6.04	7.36	6.14	6.84	6.99	5.43	5.19
Duct distance from Face (m)	1.52	1.83	0.91	1.83	0.91	1.83	0.91	1.83
Quantity @ Face (m^3/s)	0.50	0.42	0.52	0.43	0.48	0.49	0.38	0.36
Return CH_4 conc. (%)	0.1	0.05	0.05	0.1	0.05	0.05	0.05	0.05
Effic. of Forcing System (E_f, %)	92.48	84.09	96.59	96.99	94.49	94.63	92.13	99.09
Overall Effic. of System (E_o, %)	12.30	4.47	5.32	4.85	6.26	9.48	4.61	35.52

APPENDIX B

B - 10

DEVELOPMENT HEADING #20

	DEC. '93	JAN '94	FEB. 94	MAR. 94	APR. 94	MAY. 94	JUNE.94	JULY/AUG. 94
Fan Type (forcing)	Simple Exhaust				29.84 kW	29.84 kW	29.84 kW	29.84 kW
Ducting Dia. (mm)	n/a	n/a	n/a	n/a	914	914	914	914
Ducting Length (m)	n/a	n/a	n/a	n/a	121.92	106.68	97.54	128.02
Quantity to Fan (Q_{t1}, m^3/s)	n/a	n/a	n/a	n/a	12.65	18.88	19.35	19.26
Quantity through Fan (Q_f, m^3/s)	n/a	n/a	n/a	n/a	9.58	10.15	10.76	10.68
Quantity at Duct End (Q_i, m^3/s)	n/a	n/a	n/a	n/a	9.53	9.77	10.38	10.15
Duct distance from Face (m)	n/a	n/a	n/a	n/a	37.19	29.26	42.67	30.48
Quantity @ Face (Q_e, m^3/s)	n/a	n/a	n/a	n/a	0.48	0.78	0.52	0.67
Fan Type (Exhausting)	n/a	n/a	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW
Ducting Dia. (mm)	n/a	n/a	762	762	762	762	762	762
Ducting Length (m)	n/a	n/a	39.62	50.29	45.11	40.23	51.82	39.62
Quantity at Duct End (m^3/s)	n/a	n/a	7.74	8.5	7.27	7.79	7.27	7.55
Duct distance from Face (m)	n/a	n/a	0.91	1.22	0.91	1.83	0.91	0.91
Quantity @ Face (m^3/s)	n/a	n/a	0.54	0.60	0.51	0.55	0.51	0.53
Return CH_4 conc. (%)	0.1	0.05	0.1	0.15	0.05	0.05	0.05	0.1
Effic. of Forcing System (E_f, %)	n/a	n/a	n/a	n/a	99.48	96.26	96.47	95.04
Overall Effic. of System (E_o, %)	n/a	n/a	n/a	n/a	5.31	7.69	4.82	6.32

APPENDIX B

B - 11

DEVELOPMENT HEADING #22

	DEC. '93	JAN '94	FEB. 94	MAR. 94	APR. 94	MAY. 94	JUNE.94	JULY/AUG. 94
Fan Type (forcing)	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW	37.3 kW
Ducting Dia. (mm)	762	762	762	762	762	762	762	762
Ducting Length (m)	518.16	563.88	609.6	701.04	762	792.48	792.48	792.48
Quantity to Fan (Q_{t1}, m^3/s)	8.35	8.68	8.68	8.6	8.31	8.87	8.83	8.5
Quantity through Fan (Q_f, m^3/s)	7.17	6.51	6.98	6.32	6.14	6.51	6.56	5.9
Quantity at Duct End (Q_i, m^3/s)	4.48	4.48	3.78	4.01	3.96	3.3	4.25	2.5
Duct distance from Face (m)	26.21	40.23	31.39	32	38.1	33.58	32	1.83
Quantity @ Face (Q_e, m^3/s)	0.25	0.22	0.19	0.20	0.20	0.17	0.21	2.44
Fan Type (Exhausting)	7.46 kW	7.46 kW	7.46 kW	7.46 kW	7.46 kW	7.46 kW	n/a	n/a
Ducting Dia. (mm)	610	610	610	610	610	610	n/a	n/a
Ducting Length (m)	48.77	54.86	48.46	47.24	43.59	53.34	n/a	n/a
Quantity at Duct End (m^3/s)	3.68	3.3	2.83	2.93	2.83	2.54	n/a	n/a
Duct distance from Face (m)	1.22	1.52	1.22	1.22	1.83	1.52	n/a	n/a
Quantity @ Face (m^3/s)	0.26	0.23	0.20	0.21	0.20	0.18	n/a	n/a
Return CH_4 conc. (%)	0.25	0.1	0.15	0.15	0.2	0.15	0.1	0.05
Effic. of Forcing System (E_f, %)	62.48	68.82	54.15	63.45	64.50	50.69	64.79	42.37
Overall Effic. of System (E_o, %)	3.59	3.55	2.84	3.25	3.23	2.73	3.24	41.36

APPENDIX C

RESULTS OF AUXILIARY VENTILATION SURVEY AT HEADING

NUMBER 11

APPENDIX C

C - 1

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

	(cfm)	(m^3/s)
Intake Quantity (cfm)	9690	4.57
Return Quantity (cfm)	7850	3.70
Methane concentration in Intake Air	0.15	0.15
Air Quantity reaching face	484.5	3.56
Distance of duct from face (m)		14.00
Volume of Room (Heading) (m^3)		698.88

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
09:17:08	0.208	0.215	0.220	0.265	0.004	0.004	4.01	3.92	18.32	17.90
09:18:08	0.198	0.210	0.215	0.240	0.003	0.004	4.13	3.98	18.89	18.18
09:19:08	0.190	0.200	0.205	0.225	0.003	0.003	4.23	4.10	19.34	18.75
09:20:08	0.195	0.205	0.220	0.250	0.002	0.003	4.16	4.04	19.04	18.46
09:21:08	0.183	0.193	0.225	0.260	0.003	0.003	4.33	4.20	19.81	19.19
09:22:08	0.185	0.205	0.200	0.235	0.002	0.002	4.30	4.04	19.65	18.46
09:23:08	0.190	0.215	0.215	0.240	0.002	0.003	4.23	3.92	19.34	17.90
09:24:08	0.198	0.208	0.225	0.270	0.002	0.004	4.13	4.01	18.89	18.32
09:25:08	0.190	0.200	0.225	0.285	0.003	0.003	4.23	4.10	19.34	18.75
09:26:08	0.185	0.200	0.210	0.285	0.002	0.003	4.30	4.10	19.65	18.75

APPENDIX C									C - 2	
AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11										
	CORRELATED TIMES						PURE METHANE CONCENTRATION			
Time	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
(hr.)	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
09:27:08	0.173	0.185	0.280	0.450	0.001	0.002	4.48	4.30	20.47	19.65
09:28:08	0.175	0.190	0.215	0.305	0.001	0.002	4.44	4.23	20.30	19.34
09:29:08	0.175	0.190	0.220	0.260	0.001	0.002	4.44	4.23	20.30	19.34
09:30:08	0.173	0.185	0.250	0.370	0.001	0.002	4.48	4.30	20.47	19.65
09:31:08	0.170	0.180	0.250	0.405	0.001	0.002	4.51	4.37	20.64	19.97
09:32:08	0.175	0.180	0.225	0.280	0.001	0.002	4.44	4.37	20.30	19.97
09:33:08	0.170	0.190	0.210	0.245	0.001	0.002	4.51	4.23	20.64	19.34
09:34:08	0.170	0.180	0.230	0.350	0.001	0.002	4.51	4.37	20.64	19.97
09:35:08	0.170	0.180	0.215	0.270	0.001	0.002	4.51	4.37	20.64	19.97
09:36:08	0.175	0.180	0.260	0.405	0.001	0.002	4.44	4.37	20.30	19.97
09:37:08	0.178	0.190	0.225	0.330	0.002	0.002	4.40	4.23	20.14	19.34
09:38:08	0.175	0.190	0.230	0.320	0.001	0.002	4.44	4.23	20.30	19.34
09:39:08	0.183	0.185	0.225	0.285	0.002	0.002	4.33	4.30	19.81	19.65
09:40:08	0.185	0.190	0.255	0.360	0.002	0.002	4.30	4.23	19.65	19.34
09:41:08	0.185	0.195	0.210	0.255	0.002	0.003	4.30	4.16	19.65	19.04
09:42:08	0.185	0.195	0.210	0.260	0.002	0.003	4.30	4.16	19.65	19.04
09:43:08	0.185	0.190	0.205	0.240	0.002	0.002	4.30	4.23	19.65	19.34
09:44:08	0.185	0.195	0.200	0.230	0.002	0.003	4.30	4.16	19.65	19.04

APPENDIX C									C - 3	
AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11										
	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
09:45:08	0.183	0.190	0.200	0.235	0.002	0.002	4.33	4.23	19.81	19.34
09:46:08	0.180	0.190	0.220	0.400	0.002	0.002	4.37	4.23	19.97	19.34
09:47:08	0.180	0.185	0.210	0.270	0.002	0.002	4.37	4.30	19.97	19.65
09:48:08	0.180	0.185	0.215	0.275	0.002	0.002	4.37	4.30	19.97	19.65
09:49:08	0.180	0.190	0.240	0.360	0.002	0.002	4.37	4.23	19.97	19.34
09:50:08	0.180	0.185	0.260	0.400	0.002	0.002	4.37	4.30	19.97	19.65
09:51:08	0.180	0.190	0.230	0.355	0.002	0.002	4.37	4.23	19.97	19.34
09:52:08	0.175	0.190	0.230	0.310	0.001	0.002	4.44	4.23	20.30	19.34
09:53:08	0.170	0.185	0.245	0.350	0.001	0.002	4.51	4.30	20.64	19.65
09:54:08	0.178	0.185	0.220	0.320	0.002	0.002	4.40	4.30	20.14	19.65
09:55:08	0.178	0.185	0.205	0.245	0.002	0.002	4.40	4.30	20.14	19.65
09:56:08	0.180	0.185	0.215	0.365	0.002	0.002	4.37	4.30	19.97	19.65
09:57:08	0.173	0.185	0.210	0.260	0.001	0.002	4.48	4.30	20.47	19.65
09:58:08	0.168	0.180	0.200	0.250	0.001	0.002	4.55	4.37	20.81	19.97
09:59:08	0.165	0.180	0.210	0.260	0.001	0.002	4.59	4.37	20.99	19.97
10:00:08	0.173	0.180	0.205	0.275	0.001	0.002	4.48	4.37	20.47	19.97
10:01:08	0.180	0.185	0.210	0.285	0.002	0.002	4.37	4.30	19.97	19.65
10:02:08	0.185	0.195	0.210	0.325	0.002	0.003	4.30	4.16	19.65	19.04
10:03:08	0.178	0.185	0.205	0.270	0.002	0.002	4.40	4.30	20.14	19.65

APPENDIX C

C - 4

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
10:04:08	0.175	0.190	0.205	0.240	0.001	0.002	4.44	4.23	20.30	19.34
10:05:08	0.170	0.180	0.260	0.365	0.001	0.002	4.51	4.37	20.64	19.97
10:06:08	0.178	0.185	0.240	0.365	0.002	0.002	4.40	4.30	20.14	19.65
10:07:08	0.180	0.185	0.215	0.265	0.002	0.002	4.37	4.30	19.97	19.65
10:08:08	0.180	0.185	0.255	0.375	0.002	0.002	4.37	4.30	19.97	19.65
10:09:08	0.178	0.185	0.255	0.335	0.002	0.002	4.40	4.30	20.14	19.65
10:10:08	0.178	0.185	0.200	0.230	0.002	0.002	4.40	4.30	20.14	19.65
10:11:08	0.180	0.185	0.200	0.215	0.002	0.002	4.37	4.30	19.97	19.65
10:12:08	0.180	0.190	0.220	0.320	0.002	0.002	4.37	4.23	19.97	19.34
10:13:08	0.180	0.190	0.205	0.220	0.002	0.002	4.37	4.23	19.97	19.34
10:14:08	0.180	0.190	0.205	0.230	0.002	0.002	4.37	4.23	19.97	19.34
10:15:08	0.183	0.195	0.225	0.325	0.002	0.003	4.33	4.16	19.81	19.04
10:16:08	0.183	0.190	0.245	0.360	0.002	0.002	4.33	4.23	19.81	19.34
10:17:08	0.180	0.190	0.215	0.240	0.002	0.002	4.37	4.23	19.97	19.34
10:18:08	0.183	0.185	0.235	0.290	0.002	0.002	4.33	4.30	19.81	19.65
10:19:08	0.190	0.190	0.250	0.340	0.002	0.002	4.23	4.23	19.34	19.34
10:20:08	0.195	0.200	0.225	0.245	0.003	0.003	4.16	4.10	19.04	18.75
10:21:08	0.195	0.200	0.215	0.240	0.003	0.003	4.16	4.10	19.04	18.75
10:22:08	0.193	0.200	0.220	0.250	0.002	0.003	4.20	4.10	19.19	18.75

APPENDIX C

C - 5

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
10:23:08	0.190	0.200	0.225	0.260	0.002	0.003	4.23	4.10	19.34	18.75
10:24:08	0.185	0.200	0.220	0.270	0.002	0.003	4.30	4.10	19.65	18.75
10:25:08	0.188	0.195	0.205	0.225	0.002	0.003	4.26	4.16	19.50	19.04
10:26:08	0.190	0.195	0.200	0.225	0.002	0.003	4.23	4.16	19.34	19.04
10:27:08	0.178	0.190	0.195	0.220	0.002	0.002	4.40	4.23	20.14	19.34
10:28:08	0.170	0.180	0.210	0.235	0.001	0.002	4.51	4.37	20.64	19.97
10:29:08	0.170	0.185	0.200	0.225	0.001	0.002	4.51	4.30	20.64	19.65
10:30:08	0.182	0.180	0.200	0.220	0.002	0.002	4.35	4.37	19.88	19.97
10:31:08	0.178	0.185	0.200	0.230	0.002	0.002	4.40	4.30	20.14	19.65
10:32:08	0.180	0.185	0.210	0.270	0.002	0.002	4.37	4.30	19.97	19.65
10:33:08	0.178	0.180	0.210	0.250	0.002	0.002	4.40	4.37	20.14	19.97
10:34:08	0.175	0.185	0.210	0.265	0.001	0.002	4.44	4.30	20.30	19.65
10:35:08	0.175	0.180	0.200	0.230	0.001	0.002	4.44	4.37	20.30	19.97
10:36:08	0.173	0.185	0.225	0.285	0.001	0.002	4.48	4.30	20.47	19.65
10:37:08	0.183	0.195	0.280	0.380	0.002	0.003	4.33	4.16	19.81	19.04
10:38:08	0.195	0.210	0.230	0.330	0.003	0.003	4.16	3.98	19.04	18.18
10:39:08	0.163	0.180	0.220	0.260	0.001	0.002	4.63	4.37	21.17	19.97
10:40:08	0.160	0.165	0.215	0.240	0.001	0.001	4.67	4.59	21.35	20.99
10:41:08	0.160	0.165	0.240	0.320	0.001	0.001	4.67	4.59	21.35	20.99

APPENDIX C

C - 6

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
10:42:08	0.158	0.160	0.225	0.280	0.000	0.001	4.71	4.67	21.53	21.35
10:43:08	0.165	0.170	0.240	0.340	0.001	0.001	4.59	4.51	20.99	20.64
10:44:08	0.170	0.220	0.240	0.305	0.001	0.004	4.51	3.86	20.64	17.64
10:45:08	0.175	0.200	0.245	0.305	0.001	0.003	4.44	4.10	20.30	18.75
10:46:08	0.175	0.180	0.300	0.420	0.001	0.002	4.44	4.37	20.30	19.97
10:47:08	0.175	0.185	0.275	0.395	0.001	0.002	4.44	4.30	20.30	19.65
10:48:08	0.173	0.180	0.270	0.360	0.001	0.002	4.48	4.37	20.47	19.97
10:49:08	0.173	0.180	0.285	0.370	0.001	0.002	4.48	4.37	20.47	19.97
10:50:08	0.175	0.180	0.260	0.300	0.001	0.002	4.44	4.37	20.30	19.97
10:51:08	0.170	0.180	0.265	0.360	0.001	0.002	4.51	4.37	20.64	19.97
10:52:08	0.173	0.180	0.275	0.325	0.001	0.002	4.48	4.37	20.47	19.97
10:53:08	0.175	0.185	0.280	0.380	0.001	0.002	4.44	4.30	20.30	19.65
10:54:08	0.173	0.180	0.255	0.300	0.001	0.002	4.48	4.37	20.47	19.97
10:55:08	0.170	0.180	0.280	0.395	0.001	0.002	4.51	4.37	20.64	19.97
10:56:08	0.170	0.180	0.260	0.315	0.001	0.002	4.51	4.37	20.64	19.97
10:57:08	0.175	0.180	0.255	0.325	0.001	0.002	4.44	4.37	20.30	19.97
10:58:08	0.175	0.180	0.270	0.355	0.001	0.002	4.44	4.37	20.30	19.97
10:59:08	0.175	0.180	0.280	0.335	0.001	0.002	4.44	4.37	20.30	19.97
11:00:08	0.175	0.180	0.225	0.280	0.001	0.002	4.44	4.37	20.30	19.97

APPENDIX C

C - 7

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
11:01:08	0.175	0.180	0.265	0.400	0.001	0.002	4.44	4.37	20.30	19.97
11:02:08	0.175	0.180	0.230	0.280	0.001	0.002	4.44	4.37	20.30	19.97
11:03:08	0.170	0.180	0.235	0.300	0.001	0.002	4.51	4.37	20.64	19.97
11:04:08	0.173	0.180	0.235	0.310	0.001	0.002	4.48	4.37	20.47	19.97
11:05:08	0.175	0.180	0.235	0.280	0.001	0.002	4.44	4.37	20.30	19.97
11:06:08	0.168	0.180	0.225	0.325	0.001	0.002	4.55	4.37	20.81	19.97
11:07:08	0.165	0.170	0.260	0.360	0.001	0.001	4.59	4.51	20.99	20.64
11:08:08	0.165	0.180	0.235	0.285	0.001	0.002	4.59	4.37	20.99	19.97
11:09:08	0.165	0.175	0.240	0.295	0.001	0.001	4.59	4.44	20.99	20.30
11:10:08	0.173	0.180	0.285	0.390	0.001	0.002	4.48	4.37	20.47	19.97
11:11:08	0.180	0.195	0.295	0.495	0.002	0.003	4.37	4.16	19.97	19.04
11:12:08	0.175	0.200	0.275	0.370	0.001	0.003	4.44	4.10	20.30	18.75
11:13:08	0.158	0.175	0.295	0.375	0.000	0.001	4.71	4.44	21.53	20.30
11:14:08	0.155	0.165	0.290	0.375	0.000	0.001	4.75	4.59	21.72	20.99
11:15:08	0.163	0.180	0.270	0.385	0.001	0.002	4.63	4.37	21.17	19.97
11:16:08	0.158	0.170	0.285	0.360	0.000	0.001	4.71	4.51	21.53	20.64
11:17:08	0.155	0.165	0.240	0.280	0.000	0.001	4.75	4.59	21.72	20.99
11:18:08	0.148	0.160	0.260	0.305	0.000	0.001	4.87	4.67	22.29	21.35
11:19:08	0.145	0.150	0.265	0.340	0.000	0.000	4.92	4.83	22.49	22.10

APPENDIX C

C - 8

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
11:20:08	0.145	0.150	0.255	0.325	0.000	0.000	4.92	4.83	22.49	22.10
11:21:08	0.143	0.150	0.285	0.415	0.000	0.000	4.96	4.83	22.70	22.10
11:22:08	0.145	0.150	0.260	0.295	0.000	0.000	4.92	4.83	22.49	22.10
11:23:08	0.145	0.150	0.260	0.305	0.000	0.000	4.92	4.83	22.49	22.10
11:24:08	0.150	0.160	0.275	0.360	0.000	0.001	4.83	4.67	22.10	21.35
11:25:08	0.150	0.160	0.260	0.370	0.000	0.001	4.83	4.67	22.10	21.35
11:26:08	0.150	0.160	0.250	0.305	0.000	0.001	4.83	4.67	22.10	21.35
11:27:08	0.145	0.150	0.240	0.345	0.000	0.000	4.92	4.83	22.49	22.10
11:28:08	0.145	0.150	0.260	0.325	0.000	0.000	4.92	4.83	22.49	22.10
11:29:08	0.145	0.150	0.260	0.335	0.000	0.000	4.92	4.83	22.49	22.10
11:30:08	0.150	0.160	0.250	0.310	0.000	0.001	4.83	4.67	22.10	21.35
11:31:08	0.148	0.160	0.265	0.390	0.000	0.001	4.87	4.67	22.29	21.35
11:32:08	0.145	0.150	0.235	0.280	0.000	0.000	4.92	4.83	22.49	22.10
11:33:08	0.140	0.150	0.250	0.340	-0.001	0.000	5.01	4.83	22.90	22.10
11:34:08	0.138	0.150	0.255	0.300	-0.001	0.000	5.05	4.83	23.11	22.10
11:35:08	0.135	0.140	0.265	0.320	-0.001	-0.001	5.10	5.01	23.32	22.90
11:36:08	0.138	0.140	0.275	0.350	-0.001	-0.001	5.05	5.01	23.11	22.90
11:37:08	0.143	0.145	0.255	0.315	0.000	0.000	4.96	4.92	22.70	22.49
11:38:08	0.145	0.155	0.230	0.290	0.000	0.000	4.92	4.75	22.49	21.72

APPENDIX C										C - 9
AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11										
	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
11:39:08	0.148	0.150	0.230	0.300	0.000	0.000	4.87	4.83	22.29	22.10
11:40:08	0.155	0.160	0.235	0.310	0.000	0.001	4.75	4.67	21.72	21.35
11:41:08	0.160	0.180	0.305	0.490	0.001	0.002	4.67	4.37	21.35	19.97
11:42:08	0.193	0.200	0.365	0.545	0.002	0.003	4.20	4.10	19.19	18.75
11:43:08	0.198	0.220	0.270	0.335	0.003	0.004	4.13	3.86	18.89	17.64
11:44:08	0.190	0.200	0.505	0.730	0.002	0.003	4.23	4.10	19.34	18.75
11:45:08	0.315	0.330	1.385	2.735	0.011	0.012	2.94	2.82	13.46	12.91
11:46:08	0.413	0.440	1.055	1.595	0.020	0.024	2.26	2.09	10.31	9.56
11:47:08	0.435	0.440	0.930	1.280	0.023	0.024	2.12	2.09	9.70	9.56
11:48:08	0.435	0.445	0.700	0.835	0.023	0.024	2.12	2.06	9.70	9.43
11:49:08	0.433	0.450	0.645	0.845	0.023	0.025	2.13	2.03	9.76	9.30
11:50:08	0.425	0.440	0.840	1.150	0.022	0.024	2.18	2.09	9.97	9.56
11:51:08	0.415	0.420	0.985	1.570	0.021	0.021	2.24	2.21	10.24	10.10
11:52:08	0.418	0.440	0.620	0.850	0.021	0.024	2.22	2.09	10.17	9.56
11:53:08	0.410	0.440	0.945	1.290	0.020	0.024	2.27	2.09	10.39	9.56
11:54:08	0.433	0.430	1.190	1.520	0.023	0.022	2.13	2.15	9.76	9.83
11:55:08	0.463	0.500	0.765	1.175	0.027	0.032	1.96	1.77	8.98	8.07
11:56:08	0.455	0.485	0.875	1.330	0.026	0.030	2.01	1.84	9.17	8.43
11:57:08	0.430	0.430	1.430	1.805	0.022	0.022	2.15	2.15	9.83	9.83

APPENDIX C

C - 10

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
11:58:08	0.470	0.495	0.880	1.045	0.028	0.031	1.92	1.79	8.79	8.19
11:59:08	0.495	0.510	0.735	1.080	0.031	0.034	1.79	1.72	8.19	7.84
12:00:08	0.438	0.485	0.775	1.210	0.023	0.030	2.11	1.84	9.63	8.43
12:01:08	0.393	0.440	0.595	0.995	0.018	0.024	2.38	2.09	10.89	9.56
12:02:08	0.370	0.405	0.625	0.980	0.016	0.020	2.53	2.30	11.58	10.53
12:03:08	0.345	0.365	0.495	0.920	0.014	0.015	2.71	2.57	12.40	11.74
12:04:08	0.318	0.350	0.590	0.750	0.011	0.014	2.92	2.67	13.36	12.23
12:05:08	0.305	0.320	0.435	0.570	0.010	0.011	3.02	2.90	13.83	13.27
12:06:08	0.293	0.310	0.490	0.590	0.009	0.011	3.13	2.98	14.32	13.64
12:07:08	0.263	0.305	0.455	0.595	0.007	0.010	3.41	3.02	15.58	13.83
12:08:08	0.245	0.260	0.400	0.495	0.006	0.007	3.58	3.43	16.38	15.69
12:09:08	0.235	0.235	0.470	0.855	0.005	0.005	3.69	3.69	16.87	16.87
12:10:08	0.235	0.250	0.475	0.700	0.005	0.006	3.69	3.53	16.87	16.15
12:11:08	0.225	0.245	0.465	0.625	0.004	0.006	3.80	3.58	17.37	16.38
12:12:08	0.205	0.215	0.455	0.625	0.003	0.004	4.04	3.92	18.46	17.90
12:13:08	0.205	0.210	0.405	0.500	0.003	0.003	4.04	3.98	18.46	18.18
12:14:08	0.205	0.215	0.455	0.560	0.003	0.004	4.04	3.92	18.46	17.90
12:15:08	0.195	0.210	0.415	0.525	0.003	0.003	4.16	3.98	19.04	18.18
12:16:08	0.195	0.200	0.415	0.520	0.003	0.003	4.16	4.10	19.04	18.75

APPENDIX C										C - 11
AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11										
	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
12:17:08	0.200	0.205	0.440	0.705	0.003	0.003	4.10	4.04	18.75	18.46
12:18:08	0.200	0.210	0.435	0.720	0.003	0.003	4.10	3.98	18.75	18.18
12:19:08	0.200	0.205	0.540	0.845	0.003	0.003	4.10	4.04	18.75	18.46
12:20:08	0.205	0.215	0.520	0.745	0.003	0.004	4.04	3.92	18.46	17.90
12:21:08	0.198	0.205	0.520	0.710	0.003	0.003	4.13	4.04	18.89	18.46
12:22:08	0.195	0.210	0.410	0.630	0.003	0.003	4.16	3.98	19.04	18.18
12:23:08	0.190	0.200	0.375	0.510	0.002	0.003	4.23	4.10	19.34	18.75
12:24:08	0.183	0.190	0.425	0.605	0.002	0.002	4.33	4.23	19.81	19.34
12:25:08	0.178	0.185	0.470	0.630	0.002	0.002	4.40	4.30	20.14	19.65
12:26:08	0.175	0.185	0.460	0.880	0.001	0.002	4.44	4.30	20.30	19.65
12:27:08	0.175	0.180	0.445	0.730	0.001	0.002	4.44	4.37	20.30	19.97
12:28:08	0.175	0.185	0.530	0.775	0.001	0.002	4.44	4.30	20.30	19.65
12:29:08	0.170	0.180	0.390	0.555	0.001	0.002	4.51	4.37	20.64	19.97
12:30:08	0.180	0.185	0.435	0.610	0.002	0.002	4.37	4.30	19.97	19.65
12:31:08	0.180	0.185	0.360	0.570	0.002	0.002	4.37	4.30	19.97	19.65
12:32:08	0.180	0.190	0.410	0.570	0.002	0.002	4.37	4.23	19.97	19.34
12:33:08	0.173	0.190	0.435	0.640	0.001	0.002	4.48	4.23	20.47	19.34
12:34:08	0.168	0.175	0.445	0.830	0.001	0.001	4.55	4.44	20.81	20.30
12:35:08	0.165	0.175	0.390	0.480	0.001	0.001	4.59	4.44	20.99	20.30

APPENDIX C

C - 12

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1-Outbye		CSE #3 - Face		CH_4 Lib Rate (M2)		Purging Time		Purging Quantity	
Time	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
(hr.)	(%)	(%)	(%)	(%)	(m^3/s)	(m^3/s)	(min.)	(min.)	(m^3/s)	(m^3/s)
12:36:08	0.170	0.185	0.480	0.670	0.001	0.002	4.51	4.30	20.64	19.65
12:37:08	0.163	0.170	0.365	0.505	0.001	0.001	4.63	4.51	21.17	20.64
12:38:08	0.160	0.165	0.410	0.560	0.001	0.001	4.67	4.59	21.35	20.99
12:39:08	0.160	0.170	0.425	0.590	0.001	0.001	4.67	4.51	21.35	20.64
12:40:08	0.160	0.160	0.305	0.415	0.001	0.001	4.67	4.67	21.35	21.35
12:41:08	0.165	0.180	0.475	0.750	0.001	0.002	4.59	4.37	20.99	19.97
12:42:08	0.163	0.175	0.355	0.465	0.001	0.001	4.63	4.44	21.17	20.30
12:43:08	0.158	0.165	0.385	0.485	0.000	0.001	4.71	4.59	21.53	20.99
12:44:08	0.155	0.165	0.360	0.465	0.000	0.001	4.75	4.59	21.72	20.99
12:45:08	0.160	0.165	0.380	0.500	0.001	0.001	4.67	4.59	21.35	20.99
12:46:08	0.163	0.180	0.395	0.585	0.001	0.002	4.63	4.37	21.17	19.97
12:47:08	0.160	0.165	0.345	0.525	0.001	0.001	4.67	4.59	21.35	20.99
12:48:08	0.160	0.165	0.345	0.440	0.001	0.001	4.67	4.59	21.35	20.99
12:49:08	0.163	0.165	0.390	0.550	0.001	0.001	4.63	4.59	21.17	20.99
12:50:08	0.165	0.170	0.350	0.435	0.001	0.001	4.59	4.51	20.99	20.64
12:51:08	0.160	0.160	0.360	0.460	0.001	0.001	4.67	4.67	21.35	21.35
Average	0.20	0.21	0.34	0.46	0.00	0.00	4.24	4.10	19.38	18.77
tandard Dev	0.07	0.08	0.20	0.32	0.01	0.01	0.70	0.71	3.21	3.23

[##] - Quantity of Fresh air required to dilute Methane conc. at face to Inflow conc. in 1 minute

[&&] - Quantity of fresh air required to dilute Methane conc. to Outbye conc. within 1 minute

APPENDIX C

C - 13

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

PURE METHANE CONCENTRATION				MONITORS					
	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)&&		Efficiency of System	
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
09:17:08	4.57	24.97	25.54	0.18	0.66	0.68	2.44	671.18	187.77
09:18:08	4.57	24.21	25.16	0.27	0.42	0.99	1.56	462.45	294.02
09:19:08	4.57	23.64	24.39	0.24	0.37	0.89	1.37	516.69	333.34
09:20:08	4.57	24.02	24.77	0.38	0.62	1.41	2.31	325.48	197.84
09:21:08	4.57	23.08	23.83	0.66	0.95	2.44	3.50	187.54	130.62
09:22:08	4.57	23.27	24.77	0.25	0.43	0.91	1.59	503.60	287.47
09:23:08	4.57	23.64	25.54	0.39	0.35	1.44	1.28	317.61	356.92
09:24:08	4.57	24.21	24.97	0.41	0.83	1.52	3.07	301.17	149.12
09:25:08	4.57	23.64	24.39	0.53	1.11	1.97	4.13	232.21	110.85
09:26:08	4.57	23.27	24.39	0.40	1.11	1.48	4.13	309.75	110.85
09:27:08	4.57	22.34	23.27	1.52	2.79	5.64	10.35	81.05	44.17
09:28:08	4.57	22.53	23.64	0.65	1.49	2.40	5.51	190.73	82.95
09:29:08	4.57	22.53	23.64	0.72	0.99	2.67	3.65	171.57	125.17
09:30:08	4.57	22.34	23.27	1.17	2.18	4.32	8.07	105.81	56.64
09:31:08	4.57	22.16	22.90	1.21	2.55	4.49	9.45	101.80	48.42
09:32:08	4.57	22.53	22.90	0.79	1.39	2.93	5.15	156.22	88.86
09:33:08	4.57	22.16	23.64	0.66	0.80	2.46	2.96	185.80	154.43
09:34:08	4.57	22.16	22.90	0.95	2.09	3.52	7.75	129.88	59.04

APPENDIX C

C - 14

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

PURE METHANE CONCENTRATION				MONITORS					
Time	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)&&		Efficiency of System	
(hr.)	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
09:35:08	4.57	22.16	22.90	0.74	1.27	2.74	4.72	167.18	96.83
09:36:08	4.57	22.53	22.90	1.24	2.55	4.61	9.45	99.17	48.42
09:37:08	4.57	22.71	23.64	0.75	1.74	2.76	6.43	165.57	71.12
09:38:08	4.57	22.53	23.64	0.86	1.64	3.18	6.07	143.66	75.31
09:39:08	4.57	23.08	23.27	0.66	1.36	2.44	5.03	187.54	90.85
09:40:08	4.57	23.27	23.64	1.01	2.01	3.74	7.44	122.34	61.43
09:41:08	4.57	23.27	24.02	0.40	0.84	1.48	3.12	309.75	146.35
09:42:08	4.57	23.27	24.02	0.40	0.90	1.48	3.35	309.75	136.48
09:43:08	4.57	23.27	23.64	0.32	0.73	1.20	2.72	382.46	168.06
09:44:08	4.57	23.27	24.02	0.25	0.52	0.91	1.92	503.60	237.83
09:45:08	4.57	23.08	23.64	0.29	0.67	1.07	2.48	428.77	184.71
09:46:08	4.57	22.90	23.64	0.63	2.34	2.34	8.67	195.65	52.74
09:47:08	4.57	22.90	23.27	0.48	1.19	1.80	4.40	254.70	103.85
09:48:08	4.57	22.90	23.27	0.56	1.25	2.07	4.62	220.97	99.04
09:49:08	4.57	22.90	23.64	0.90	2.01	3.35	7.44	136.48	61.43
09:50:08	4.57	22.90	23.27	1.16	2.42	4.28	8.98	106.77	50.92
09:51:08	4.57	22.90	23.64	0.77	1.97	2.86	7.28	160.17	62.81
09:52:08	4.57	22.53	23.64	0.86	1.54	3.18	5.70	143.66	80.20

APPENDIX C

C - 15

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

PURE METHANE CONCENTRATION				MONITORS					
.	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)$^{\&\&}$		Efficiency of System	
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
09:53:08	4.57	22.16	23.27	1.15	2.00	4.26	7.43	107.43	61.58
09:54:08	4.57	22.71	23.27	0.67	1.72	2.50	6.38	182.90	71.65
09:55:08	4.57	22.71	23.27	0.45	0.88	1.68	3.27	272.57	139.77
09:56:08	4.57	22.90	23.27	0.56	2.14	2.07	7.92	220.97	57.78
09:57:08	4.57	22.34	23.27	0.62	1.07	2.29	3.96	199.59	115.36
09:58:08	4.57	21.97	22.90	0.56	1.03	2.07	3.83	221.40	119.52
09:59:08	4.57	21.79	22.90	0.76	1.16	2.81	4.28	162.80	106.77
10:00:08	4.57	22.34	22.90	0.54	1.33	2.01	4.94	227.45	92.64
10:01:08	4.57	22.90	23.27	0.48	1.36	1.80	5.03	254.70	90.85
10:02:08	4.57	23.27	24.02	0.40	1.61	1.48	5.95	309.75	76.86
10:03:08	4.57	22.71	23.27	0.45	1.19	1.68	4.40	272.57	103.85
10:04:08	4.57	22.53	23.64	0.50	0.73	1.84	2.72	248.14	168.06
10:05:08	4.57	22.16	22.90	1.34	2.22	4.95	8.23	92.41	55.54
10:06:08	4.57	22.71	23.27	0.95	2.14	3.51	7.92	130.15	57.78
10:07:08	4.57	22.90	23.27	0.56	1.13	2.07	4.19	220.97	109.25
10:08:08	4.57	22.90	23.27	1.10	2.22	4.06	8.23	112.72	55.57
10:09:08	4.57	22.71	23.27	1.14	1.87	4.22	6.92	108.37	66.12
10:10:08	4.57	22.71	23.27	0.38	0.68	1.39	2.54	328.97	180.33

APPENDIX C

C - 16

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

PURE METHANE CONCENTRATION				MONITORS					
	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)&&		Efficiency of System	
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
10:11:08	4.57	22.90	23.27	0.33	0.47	1.23	1.75	372.64	261.25
10:12:08	4.57	22.90	23.64	0.63	1.64	2.34	6.07	195.65	75.31
10:13:08	4.57	22.90	23.64	0.41	0.46	1.51	1.71	301.89	267.81
10:14:08	4.57	22.90	23.64	0.41	0.60	1.51	2.23	301.89	205.50
10:15:08	4.57	23.08	24.02	0.66	1.61	2.44	5.95	187.54	76.86
10:16:08	4.57	23.08	23.64	0.93	2.01	3.43	7.44	133.31	61.43
10:17:08	4.57	22.90	23.64	0.56	0.73	2.07	2.72	220.97	168.06
10:18:08	4.57	23.08	23.27	0.79	1.41	2.95	5.24	155.28	87.34
10:19:08	4.57	23.64	23.64	0.86	1.83	3.20	6.78	143.06	67.47
10:20:08	4.57	24.02	24.39	0.45	0.64	1.67	2.36	274.36	193.46
10:21:08	4.57	24.02	24.39	0.31	0.57	1.14	2.12	402.11	215.34
10:22:08	4.57	23.83	24.39	0.42	0.70	1.56	2.60	294.02	175.95
10:23:08	4.57	23.64	24.39	0.53	0.82	1.97	3.06	232.21	149.64
10:24:08	4.57	23.27	24.39	0.54	0.94	2.02	3.50	226.59	130.83
10:25:08	4.57	23.45	24.02	0.28	0.45	1.04	1.67	440.00	274.36
10:26:08	4.57	23.64	24.02	0.16	0.45	0.60	1.67	765.43	274.36
10:27:08	4.57	22.71	23.64	0.30	0.46	1.10	1.71	417.55	267.81
10:28:08	4.57	22.16	22.90	0.66	0.84	2.46	3.11	185.80	147.25

APPENDIX C

C - 17

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

PURE METHANE CONCENTRATION				MONITORS					
	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)&&		Efficiency of System	
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
10:29:08	4.57	22.16	23.27	0.51	0.62	1.89	2.28	241.58	200.57
10:30:08	4.57	23.01	22.90	0.31	0.63	1.13	2.34	404.50	195.65
10:31:08	4.57	22.71	23.27	0.38	0.68	1.39	2.54	328.97	180.33
10:32:08	4.57	22.90	23.27	0.48	1.19	1.80	4.40	254.70	103.85
10:33:08	4.57	22.71	22.90	0.53	1.03	1.96	3.83	233.51	119.52
10:34:08	4.57	22.53	23.27	0.57	1.13	2.12	4.19	215.34	109.25
10:35:08	4.57	22.53	22.90	0.42	0.77	1.56	2.86	294.02	160.17
10:36:08	4.57	22.34	23.27	0.84	1.36	3.09	5.03	147.76	90.85
10:37:08	4.57	23.08	24.02	1.35	2.10	4.99	7.77	91.72	58.85
10:38:08	4.57	24.02	25.16	0.52	1.42	1.92	5.26	237.83	86.86
10:39:08	4.57	21.61	22.90	0.95	1.16	3.53	4.28	129.60	106.77
10:40:08	4.57	21.42	21.79	0.93	1.18	3.44	4.36	132.88	104.78
10:41:08	4.57	21.42	21.79	1.27	2.08	4.72	7.72	96.83	59.27
10:42:08	4.57	21.24	21.42	1.12	1.76	4.15	6.52	110.08	70.16
10:43:08	4.57	21.79	22.16	1.18	2.18	4.36	8.07	104.78	56.64
10:44:08	4.57	22.16	25.93	1.08	1.03	4.02	3.81	113.85	120.18
10:45:08	4.57	22.53	24.39	1.06	1.33	3.92	4.92	116.69	93.04
10:46:08	4.57	22.53	22.90	1.69	2.66	6.28	9.87	72.84	46.34

APPENDIX C									C - 18	
AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11										
PURE METHANE CONCENTRATION				MONITORS						
	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)[&&]		Efficiency of System		
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)	
10:47:08	4.57	22.53	23.27	1.42	2.38	5.26	8.84	86.86	51.76	
10:48:08	4.57	22.34	22.90	1.41	2.18	5.22	8.07	87.63	56.64	
10:49:08	4.57	22.34	22.90	1.58	2.27	5.85	8.39	78.20	54.49	
10:50:08	4.57	22.53	22.90	1.24	1.61	4.61	5.95	99.17	76.86	
10:51:08	4.57	22.16	22.90	1.40	2.18	5.17	8.07	88.44	56.64	
10:52:08	4.57	22.34	22.90	1.47	1.86	5.43	6.88	84.18	66.45	
10:53:08	4.57	22.53	23.27	1.48	2.26	5.47	8.38	83.53	54.54	
10:54:08	4.57	22.34	22.90	1.23	1.61	4.55	5.95	100.45	76.86	
10:55:08	4.57	22.16	22.90	1.57	2.47	5.81	9.15	78.68	49.96	
10:56:08	4.57	22.16	22.90	1.34	1.76	4.95	6.52	92.41	70.16	
10:57:08	4.57	22.53	22.90	1.18	1.86	4.39	6.88	104.29	66.45	
10:58:08	4.57	22.53	22.90	1.36	2.14	5.05	7.91	90.54	57.81	
10:59:08	4.57	22.53	22.90	1.48	1.95	5.47	7.24	83.53	63.21	
11:00:08	4.57	22.53	22.90	0.79	1.39	2.93	5.15	156.22	88.86	
11:01:08	4.57	22.53	22.90	1.30	2.51	4.83	9.30	94.62	49.17	
11:02:08	4.57	22.53	22.90	0.86	1.39	3.18	5.15	143.66	88.86	
11:03:08	4.57	22.16	22.90	1.02	1.61	3.77	5.95	121.26	76.86	
11:04:08	4.57	22.34	22.90	0.97	1.71	3.60	6.33	126.98	72.22	

APPENDIX C

C - 19

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

PURE METHANE CONCENTRATION				MONITORS					
	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)&&		Efficiency of System	
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
11:05:08	4.57	22.53	22.90	0.93	1.39	3.43	5.15	133.18	88.86
11:06:08	4.57	21.97	22.90	0.93	1.86	3.44	6.88	133.04	66.45
11:07:08	4.57	21.79	22.16	1.43	2.36	5.30	8.74	86.34	52.33
11:08:08	4.57	21.79	22.90	1.11	1.44	4.12	5.35	111.02	85.44
11:09:08	4.57	21.79	22.53	1.18	1.64	4.36	6.08	104.78	75.19
11:10:08	4.57	22.34	22.90	1.58	2.43	5.85	9.01	78.20	50.78
11:11:08	4.57	22.90	24.02	1.55	2.93	5.75	10.85	79.47	42.15
11:12:08	4.57	22.53	24.39	1.42	1.93	5.26	7.17	86.86	63.82
11:13:08	4.57	21.24	22.53	1.97	2.40	7.31	8.88	62.56	51.51
11:14:08	4.57	21.06	21.79	1.97	2.58	7.30	9.56	62.67	47.82
11:15:08	4.57	21.61	22.90	1.60	2.39	5.91	8.86	77.33	51.64
11:16:08	4.57	21.24	22.16	1.86	2.36	6.91	8.74	66.20	52.33
11:17:08	4.57	21.06	21.79	1.37	1.66	5.09	6.16	89.80	74.24
11:18:08	4.57	20.51	21.42	1.78	2.03	6.60	7.51	69.26	60.86
11:19:08	4.57	20.33	20.70	1.90	2.57	7.02	9.53	65.11	47.98
11:20:08	4.57	20.33	20.70	1.77	2.43	6.58	9.01	69.55	50.78
11:21:08	4.57	20.15	20.70	2.18	3.20	8.07	11.85	56.64	38.58
11:22:08	4.57	20.33	20.70	1.84	2.13	6.80	7.88	67.23	58.05

APPENDIX C

C - 20

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

PURE METHANE CONCENTRATION				MONITORS					
	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)$^{\&\&}$		Efficiency of System	
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
11:23:08	4.57	20.33	20.70	1.84	2.23	6.80	8.27	67.23	55.32
11:24:08	4.57	20.70	21.42	1.91	2.55	7.06	9.45	64.77	48.42
11:25:08	4.57	20.70	21.42	1.73	2.64	6.41	9.76	71.38	46.83
11:26:08	4.57	20.70	21.42	1.61	2.03	5.95	7.51	76.86	60.86
11:27:08	4.57	20.33	20.70	1.58	2.62	5.87	9.70	77.91	47.14
11:28:08	4.57	20.33	20.70	1.84	2.43	6.80	9.01	67.23	50.78
11:29:08	4.57	20.33	20.70	1.84	2.53	6.80	9.36	67.23	48.86
11:30:08	4.57	20.70	21.42	1.61	2.08	5.95	7.70	76.86	59.36
11:31:08	4.57	20.51	21.42	1.84	2.80	6.82	10.38	67.01	44.07
11:32:08	4.57	20.33	20.70	1.52	1.96	5.62	7.27	81.31	62.90
11:33:08	4.57	19.97	20.70	1.82	2.57	6.75	9.53	67.71	47.98
11:34:08	4.57	19.79	20.70	1.94	2.18	7.19	8.07	63.57	56.64
11:35:08	4.57	19.61	19.97	2.12	2.60	7.86	9.63	58.21	47.49
11:36:08	4.57	19.79	19.97	2.18	2.88	8.07	10.67	56.64	42.85
11:37:08	4.57	20.15	20.33	1.83	2.44	6.78	9.04	67.47	50.61
11:38:08	4.57	20.33	21.06	1.45	1.97	5.37	7.30	85.10	62.67
11:39:08	4.57	20.51	20.70	1.40	2.18	5.17	8.07	88.38	56.64
11:40:08	4.57	21.06	21.42	1.31	2.08	4.85	7.70	94.34	59.36

APPENDIX C								C - 21	
AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11									
PURE METHANE CONCENTRATION				MONITORS					
	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)[&&]		Efficiency of System	
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
11:41:08	4.57	21.42	22.90	2.03	3.15	7.51	11.66	60.86	39.20
11:42:08	4.57	23.83	24.39	2.01	3.15	7.45	11.68	61.37	39.16
11:43:08	4.57	24.21	25.93	0.98	1.32	3.64	4.90	125.56	93.37
11:44:08	4.57	23.64	24.39	3.07	4.07	11.39	15.08	40.16	30.32
11:45:08	4.57	33.99	35.41	4.66	6.65	17.25	24.63	26.51	18.57
11:46:08	4.57	44.34	47.82	2.95	4.05	10.94	15.00	41.81	30.49
11:47:08	4.57	47.17	47.82	2.39	3.36	8.85	12.44	51.67	36.77
11:48:08	4.57	47.17	48.49	1.50	1.98	5.54	7.33	82.53	62.38
11:49:08	4.57	46.84	49.17	1.26	1.98	4.66	7.34	98.24	62.31
11:50:08	4.57	45.88	47.82	2.14	3.02	7.94	11.19	57.63	40.87
11:51:08	4.57	44.64	45.26	2.72	4.15	10.07	15.36	45.42	29.78
11:52:08	4.57	44.95	47.82	1.24	2.07	4.61	7.67	99.29	59.63
11:53:08	4.57	44.03	47.82	2.63	3.38	9.73	12.53	47.02	36.50
11:54:08	4.57	46.84	46.52	3.18	3.97	11.79	14.71	38.79	31.09
11:55:08	4.57	50.92	56.64	1.58	2.69	5.86	9.95	78.02	45.95
11:56:08	4.57	49.86	54.26	2.06	3.17	7.62	11.75	60.04	38.92
11:57:08	4.57	46.52	46.52	3.78	4.51	14.00	16.71	32.67	27.37
11:58:08	4.57	52.00	55.83	1.97	2.35	7.31	8.70	62.60	52.54

APPENDIX C

C - 22

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

PURE METHANE CONCENTRATION				MONITORS					
	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)[&&]		Efficiency of System	
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
11:59:08	4.57	55.83	58.31	1.24	2.36	4.60	8.74	99.32	52.33
12:00:08	4.57	47.49	54.26	1.80	2.87	6.66	10.65	68.66	42.94
12:01:08	4.57	41.98	47.82	1.31	2.57	4.85	9.50	94.37	48.12
12:02:08	4.57	39.49	43.44	1.65	2.78	6.11	10.29	74.89	44.43
12:03:08	4.57	36.89	38.96	1.14	2.91	4.21	10.77	108.75	42.47
12:04:08	4.57	34.22	37.40	1.95	2.40	7.22	8.88	63.36	51.51
12:05:08	4.57	33.06	34.46	1.12	1.82	4.14	6.72	110.58	68.01
12:06:08	4.57	31.94	33.52	1.62	2.02	6.01	7.50	76.10	61.01
12:07:08	4.57	29.35	33.06	1.73	2.10	6.41	7.78	71.38	58.75
12:08:08	4.57	27.91	29.15	1.54	2.02	5.71	7.50	80.09	60.98
12:09:08	4.57	27.11	27.11	2.18	4.06	8.07	15.04	56.64	30.40
12:10:08	4.57	27.11	28.32	2.21	3.24	8.20	11.99	55.79	38.13
12:11:08	4.57	26.32	27.91	2.28	2.94	8.46	10.91	54.08	41.92
12:12:08	4.57	24.77	25.54	2.51	3.36	9.29	12.43	49.24	36.79
12:13:08	4.57	24.77	25.16	2.14	2.73	7.93	10.10	57.66	45.26
12:14:08	4.57	24.77	25.54	2.51	3.01	9.29	11.15	49.24	41.01
12:15:08	4.57	24.02	25.16	2.37	2.88	8.80	10.67	51.98	42.85
12:16:08	4.57	24.02	24.39	2.37	3.00	8.80	11.13	51.98	41.09

APPENDIX C

C - 23

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

PURE METHANE CONCENTRATION				MONITORS					
	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)&&		Efficiency of System	
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
12:17:08	4.57	24.39	24.77	2.48	3.88	9.18	14.39	49.80	31.79
12:18:08	4.57	24.39	25.16	2.44	3.87	9.05	14.35	50.53	31.86
12:19:08	4.57	24.39	24.77	3.12	4.45	11.57	16.50	39.53	27.72
12:20:08	4.57	24.77	25.54	2.93	3.91	10.84	14.48	42.18	31.59
12:21:08	4.57	24.21	24.77	3.04	3.91	11.28	14.47	40.56	31.60
12:22:08	4.57	24.02	25.16	2.34	3.45	8.66	12.80	52.83	35.74
12:23:08	4.57	23.64	24.39	2.14	2.94	7.92	10.90	57.75	41.94
12:24:08	4.57	23.08	23.64	2.66	3.64	9.85	13.49	46.44	33.90
12:25:08	4.57	22.71	23.27	3.06	3.85	11.34	14.27	40.32	32.04
12:26:08	4.57	22.53	23.27	3.04	4.90	11.26	18.17	40.62	25.17
12:27:08	4.57	22.53	22.90	2.93	4.40	10.87	16.31	42.07	28.04
12:28:08	4.57	22.53	23.27	3.48	4.50	12.91	16.69	35.43	27.41
12:29:08	4.57	22.16	22.90	2.61	3.54	9.67	13.12	47.28	34.87
12:30:08	4.57	22.90	23.27	2.77	3.75	10.28	13.90	44.49	32.91
12:31:08	4.57	22.90	23.27	2.18	3.54	8.07	13.11	56.64	34.89
12:32:08	4.57	22.90	23.64	2.59	3.45	9.59	12.80	47.69	35.74
12:33:08	4.57	22.34	23.64	2.91	3.82	10.77	14.15	42.45	32.33
12:34:08	4.57	21.97	22.53	3.07	4.89	11.38	18.13	40.18	25.22
12:35:08	4.57	21.79	22.53	2.70	3.17	10.02	11.75	45.64	38.91

APPENDIX C

C - 24

AUXILIARY VENTILATION SURVEY AT DEVELOPMENT HEADING #11

PURE METHANE CONCENTRATION				MONITORS					
	Actual	Efficiency of System		Purging Time (ordinary)		Purging Qnty. (1 min)[&&]		Efficiency of System	
Time	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
12:36:08	4.57	22.16	23.27	3.26	4.05	12.09	14.99	37.82	30.51
12:37:08	4.57	21.61	22.16	2.54	3.42	9.43	12.68	48.52	36.06
12:38:08	4.57	21.42	21.79	2.96	3.84	10.96	14.23	41.72	32.13
12:39:08	4.57	21.42	22.16	3.07	3.91	11.38	14.49	40.19	31.55
12:40:08	4.57	21.42	21.42	2.03	3.00	7.51	11.10	60.86	41.19
12:41:08	4.57	21.79	22.90	3.32	4.49	12.32	16.62	37.13	27.51
12:42:08	4.57	21.61	22.53	2.46	3.07	9.10	11.38	50.24	40.18
12:43:08	4.57	21.24	21.79	2.81	3.39	10.41	12.56	43.93	36.41
12:44:08	4.57	21.06	21.79	2.65	3.26	9.82	12.07	46.59	37.89
12:45:08	4.57	21.42	21.79	2.72	3.49	10.08	12.91	45.39	35.41
12:46:08	4.57	21.61	22.90	2.79	3.71	10.35	13.73	44.20	33.31
12:47:08	4.57	21.42	21.79	2.42	3.64	8.95	13.48	51.10	33.92
12:48:08	4.57	21.42	21.79	2.42	3.08	8.95	11.42	51.10	40.03
12:49:08	4.57	21.61	21.79	2.75	3.79	10.20	14.02	44.85	32.61
12:50:08	4.57	21.79	22.16	2.36	2.95	8.76	10.94	52.21	41.79
12:51:08	4.57	21.42	21.42	2.55	3.32	9.45	12.30	48.42	37.18
Average	4.57	24.72	25.63	1.46	2.19	5.43	8.12	138.75	81.07
Standard Dev.	0.00	6.93	7.59	0.89	1.12	3.29	4.14	119.16	62.21

[##] - Quantity of Fresh air required to dilute Methane conc. at face to Inflow conc. in 1 minute

[&&] - Quantity of fresh air required to dilute Methane conc. to Outbye conc. within 1 minute

APPENDIX D

RESULTS OF AUXILIARY VENTILATION SURVEY AT HEADING NUMBER 9

APPENDIX D

D - 1

AUXILIARY VENTILATION SURVEY AT HEADING #9

	(cfm)	(m^3/s)
Intake Air Quantity	14350	6.77
Return Air Quantity	6770	3.20
Air Quantity at face	5872.02	2.77
Volume of Heading (m^3)		1160.64
Distance of duct from face (m)		17.50

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1 93m Outbye		CSE #3 AT FACE		CH_4 Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)##	
Time	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max
(hr.)	(%)	(%)	(%)	(%)	$Q_{CH4\,(Avg.)}$	$Q_{CH4\,(Max.)}$	(min)	(min)	(m^3/s)	(m^3/s)
08:15:51	0.200	0.205	0.425	0.480	0.0020	0.0022	4.60	4.53	31.13	30.66
08:16:51	0.195	0.200	0.418	0.445	0.0018	0.0020	4.67	4.60	31.62	31.13
08:17:51	0.200	0.205	0.365	0.380	0.0020	0.0022	4.60	4.53	31.13	30.66
08:18:51	0.195	0.205	0.383	0.403	0.0018	0.0022	4.67	4.53	31.62	30.66
08:19:51	0.190	0.200	0.405	0.438	0.0016	0.0020	4.74	4.60	32.13	31.13
08:20:51	0.190	0.195	0.400	0.440	0.0016	0.0018	4.74	4.67	32.13	31.62
08:21:51	0.190	0.200	0.418	0.455	0.0016	0.0020	4.74	4.60	32.13	31.13
08:22:51	0.220	0.255	0.390	0.458	0.0029	0.0045	4.32	3.90	29.29	26.43
08:23:51	0.245	0.260	0.310	0.370	0.0040	0.0047	4.02	3.85	27.21	26.06

APPENDIX D **D - 2**

AUXILIARY VENTILATION SURVEY AT HEADING #9

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
Time	CSE #1 93m Outbye		CSE #3 AT FACE		CH_4 Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)&&	
(hr.)	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max
08:24:51	0.220	0.250	0.361	0.397	0.0029	0.0043	4.32	3.96	29.29	26.82
08:25:51	0.230	0.260	0.288	0.405	0.0033	0.0047	4.20	3.85	28.43	26.06
08:26:51	0.285	0.365	0.333	0.550	0.0060	0.0108	3.59	2.88	24.28	19.50
08:27:51	0.285	0.320	0.325	0.450	0.0060	0.0080	3.59	3.25	24.28	22.04
08:28:51	0.240	0.260	0.293	0.325	0.0038	0.0047	4.08	3.85	27.61	26.06
08:29:51	0.225	0.240	0.283	0.323	0.0031	0.0038	4.26	4.08	28.85	27.61
08:30:51	0.225	0.240	0.288	0.330	0.0031	0.0038	4.26	4.08	28.85	27.61
08:31:51	0.235	0.270	0.293	0.343	0.0036	0.0053	4.14	3.74	28.01	25.33
08:32:51	0.310	0.415	0.475	0.718	0.0074	0.0145	3.35	2.51	22.66	17.01
08:33:51	0.425	0.470	0.725	1.050	0.0153	0.0193	2.44	2.16	16.55	14.61
08:34:51	0.435	0.470	0.678	0.883	0.0161	0.0193	2.38	2.16	16.10	14.61
08:35:51	0.370	0.420	0.720	0.840	0.0112	0.0149	2.84	2.48	19.23	16.78
08:36:51	0.345	0.370	0.590	0.705	0.0095	0.0112	3.04	2.84	20.59	19.23
08:37:51	0.335	0.360	0.453	0.545	0.0089	0.0105	3.12	2.92	21.16	19.76
08:38:51	0.275	0.305	0.453	0.533	0.0055	0.0071	3.69	3.39	24.97	22.97
08:39:51	0.240	0.260	0.428	0.558	0.0038	0.0047	4.08	3.85	27.61	26.06
08:40:51	0.230	0.235	0.373	0.518	0.0033	0.0036	4.20	4.14	28.43	28.01
08:41:51	0.235	0.260	0.353	0.455	0.0036	0.0047	4.14	3.85	28.01	26.06

APPENDIX D

D - 3

AUXILIARY VENTILATION SURVEY AT HEADING #9

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1 93m Outbye		CSE #3 AT FACE		CH_4 Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)[&&]	
Time	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max
(hr.)	(%)	(%)	(%)	(%)	$Q_{CH4\ (Avg.)}$	$Q_{CH4\ (Max.)}$	(min)	(min)	(m^3/s)	(m^3/s)
08:42:51	0.305	0.350	0.375	0.468	0.0071	0.0098	3.39	3.00	22.97	20.31
08:43:51	0.385	0.400	0.380	0.488	0.0122	0.0133	2.73	2.62	18.46	17.72
08:44:51	0.320	0.365	0.360	0.485	0.0080	0.0108	3.25	2.88	22.04	19.50
08:45:51	0.290	0.295	0.328	0.403	0.0063	0.0066	3.54	3.49	23.95	23.61
08:46:51	0.280	0.300	0.318	0.348	0.0058	0.0068	3.64	3.44	24.62	23.29
08:47:51	0.245	0.270	0.407	0.500	0.0040	0.0053	4.02	3.74	27.21	25.33
08:48:51	0.250	0.280	0.365	0.395	0.0043	0.0058	3.96	3.64	26.82	24.62
08:49:51	0.265	0.280	0.393	0.420	0.0050	0.0058	3.79	3.64	25.69	24.62
08:50:51	0.245	0.250	0.440	0.498	0.0040	0.0043	4.02	3.96	27.21	26.82
08:51:51	0.240	0.250	0.508	0.565	0.0038	0.0043	4.08	3.96	27.61	26.82
08:52:51	0.235	0.240	0.540	0.580	0.0036	0.0038	4.14	4.08	28.01	27.61
08:53:51	0.245	0.250	0.513	0.573	0.0040	0.0043	4.02	3.96	27.21	26.82
08:54:51	0.240	0.245	0.460	0.535	0.0038	0.0040	4.08	4.02	27.61	27.21
08:55:51	0.240	0.245	0.433	0.493	0.0038	0.0040	4.08	4.02	27.61	27.21
08:56:51	0.245	0.255	0.418	0.450	0.0040	0.0045	4.02	3.90	27.21	26.43
08:57:51	0.260	0.265	0.410	0.450	0.0047	0.0050	3.85	3.79	26.06	25.69
08:58:51	0.255	0.265	0.443	0.510	0.0045	0.0050	3.90	3.79	26.43	25.69

APPENDIX D

D - 4

AUXILIARY VENTILATION SURVEY AT HEADING #9

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1 93m Outbye		CSE #3 AT FACE		CH$_4$ Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)$^{\&\&}$	
Time	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max
(hr.)	(%)	(%)	(%)	(%)	$Q_{CH4\ (Avg.)}$	$Q_{CH4\ (Max.)}$	(min)	(min)	(m^3/s)	(m^3/s)
08:59:51	0.245	0.250	0.458	0.535	0.0040	0.0043	4.02	3.96	27.21	26.82
09:00:51	0.245	0.250	0.458	0.535	0.0040	0.0043	4.02	3.96	27.21	26.82
09:01:51	0.240	0.245	0.483	0.550	0.0038	0.0040	4.08	4.02	27.61	27.21
09:02:51	0.240	0.245	0.440	0.493	0.0038	0.0040	4.08	4.02	27.61	27.21
09:03:51	0.240	0.245	0.410	0.445	0.0038	0.0040	4.08	4.02	27.61	27.21
09:04:51	0.240	0.245	0.435	0.473	0.0038	0.0040	4.08	4.02	27.61	27.21
09:05:51	0.245	0.255	0.428	0.460	0.0040	0.0045	4.02	3.90	27.21	26.43
09:06:51	0.260	0.270	0.440	0.473	0.0047	0.0053	3.85	3.74	26.06	25.33
09:07:51	0.270	0.280	0.445	0.495	0.0053	0.0058	3.74	3.64	25.33	24.62
09:08:51	0.280	0.290	0.438	0.480	0.0058	0.0063	3.64	3.54	24.62	23.95
09:09:51	0.300	0.305	0.440	0.468	0.0068	0.0071	3.44	3.39	23.29	22.97
09:10:51	0.305	0.310	0.445	0.478	0.0071	0.0074	3.39	3.35	22.97	22.66
09:11:51	0.310	0.320	0.435	0.473	0.0074	0.0080	3.35	3.25	22.66	22.04
09:12:51	0.320	0.325	0.430	0.460	0.0080	0.0083	3.25	3.21	22.04	21.74
09:13:51	0.320	0.325	0.463	0.488	0.0080	0.0083	3.25	3.21	22.04	21.74
09:14:51	0.325	0.335	0.475	0.498	0.0083	0.0089	3.21	3.12	21.74	21.16
09:15:51	0.330	0.330	0.458	0.480	0.0086	0.0086	3.17	3.17	21.45	21.45

APPENDIX D

D - 5

AUXILIARY VENTILATION SURVEY AT HEADING #9

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1 93m Outbye		CSE #3 AT FACE		CH_4 Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)$^{\&\&}$	
Time	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max
(hr.)	(%)	(%)	(%)	(%)	$Q_{CH4\ (Avg.)}$	$Q_{CH4\ (Max.)}$	(min)	(min)	(m^3/s)	(m^3/s)
09:16:51	0.330	0.340	0.458	0.485	0.0086	0.0092	3.17	3.08	21.45	20.87
09:17:51	0.330	0.340	0.460	0.490	0.0086	0.0092	3.17	3.08	21.45	20.87
09:18:51	0.335	0.340	0.455	0.483	0.0089	0.0092	3.12	3.08	21.16	20.87
09:19:51	0.335	0.340	0.458	0.493	0.0089	0.0092	3.12	3.08	21.16	20.87
09:20:51	0.330	0.335	0.453	0.480	0.0086	0.0089	3.17	3.12	21.45	21.16
09:21:51	0.325	0.330	0.445	0.463	0.0083	0.0086	3.21	3.17	21.74	21.45
09:22:51	0.325	0.330	0.448	0.465	0.0083	0.0086	3.21	3.17	21.74	21.45
09:23:51	0.325	0.325	0.450	0.463	0.0083	0.0083	3.21	3.21	21.74	21.74
09:24:51	0.320	0.325	0.445	0.460	0.0080	0.0083	3.25	3.21	22.04	21.74
09:25:51	0.320	0.320	0.445	0.470	0.0080	0.0080	3.25	3.25	22.04	22.04
09:26:51	0.315	0.320	0.450	0.473	0.0077	0.0080	3.30	3.25	22.35	22.04
09:27:51	0.305	0.315	0.445	0.473	0.0071	0.0077	3.39	3.30	22.97	22.35
09:28:51	0.315	0.320	0.438	0.473	0.0077	0.0080	3.30	3.25	22.35	22.04
09:29:51	0.305	0.320	0.428	0.465	0.0071	0.0080	3.39	3.25	22.97	22.04
09:30:51	0.300	0.310	0.428	0.460	0.0068	0.0074	3.44	3.35	23.29	22.66
09:31:51	0.305	0.320	0.420	0.448	0.0071	0.0080	3.39	3.25	22.97	22.04
09:32:51	0.320	0.325	0.403	0.440	0.0080	0.0083	3.25	3.21	22.04	21.74

APPENDIX D										D - 6
AUXILIARY VENTILATION SURVEY AT HEADING #9										
	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1 93m Outbye		CSE #3 AT FACE		CH_4 Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)&&	
Time	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max
(hr.)	(%)	(%)	(%)	(%)	$Q_{CH4\,(Avg.)}$	$Q_{CH4\,(Max.)}$	(min)	(min)	(m^3/s)	(m^3/s)
09:33:51	0.320	0.320	0.385	0.413	0.0080	0.0080	3.25	3.25	22.04	22.04
09:34:51	0.305	0.320	0.365	0.388	0.0071	0.0080	3.39	3.25	22.97	22.04
09:35:51	0.300	0.305	0.365	0.395	0.0068	0.0071	3.44	3.39	23.29	22.97
09:36:51	0.290	0.295	0.370	0.423	0.0063	0.0066	3.54	3.49	23.95	23.61
09:37:51	0.280	0.290	0.360	0.405	0.0058	0.0063	3.64	3.54	24.62	23.95
09:38:51	0.280	0.285	0.350	0.368	0.0058	0.0060	3.64	3.59	24.62	24.28
09:39:51	0.280	0.285	0.355	0.378	0.0058	0.0060	3.64	3.59	24.62	24.28
09:40:51	0.275	0.280	0.355	0.383	0.0055	0.0058	3.69	3.64	24.97	24.62
09:41:51	0.280	0.285	0.353	0.378	0.0058	0.0060	3.64	3.59	24.62	24.28
09:42:51	0.280	0.285	0.353	0.370	0.0058	0.0060	3.64	3.59	24.62	24.28
09:43:51	0.275	0.280	0.348	0.365	0.0055	0.0058	3.69	3.64	24.97	24.62
09:44:51	0.265	0.270	0.348	0.375	0.0050	0.0053	3.79	3.74	25.69	25.33
09:45:51	0.260	0.265	0.355	0.388	0.0047	0.0050	3.85	3.79	26.06	25.69
09:46:51	0.250	0.255	0.360	0.390	0.0043	0.0045	3.96	3.90	26.82	26.43
09:47:51	0.250	0.255	0.363	0.385	0.0043	0.0045	3.96	3.90	26.82	26.43
09:48:51	0.250	0.255	0.363	0.383	0.0043	0.0045	3.96	3.90	26.82	26.43
09:49:51	0.250	0.255	0.368	0.400	0.0043	0.0045	3.96	3.90	26.82	26.43

APPENDIX D										D - 7	
AUXILIARY VENTILATION SURVEY AT HEADING #9											
	CORRELATED TIMES						PURE METHANE CONCENTRATION				
	CSE #1 93m Outbye		CSE #3 AT FACE		CH_4 Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)&&		
Time	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max	
(hr.)	(%)	(%)	(%)	(%)	$Q_{CH4\ (Avg.)}$	$Q_{CH4\ (Max.)}$	(min)	(min)	(m^3/s)	(m^3/s)	
09:50:51	0.255	0.260	0.368	0.393	0.0045	0.0047	3.90	3.85	26.43	26.06	
09:51:51	0.255	0.260	0.368	0.385	0.0045	0.0047	3.90	3.85	26.43	26.06	
09:52:51	0.255	0.260	0.380	0.420	0.0045	0.0047	3.90	3.85	26.43	26.06	
09:53:51	0.255	0.260	0.378	0.420	0.0045	0.0047	3.90	3.85	26.43	26.06	
09:54:51	0.255	0.260	0.363	0.388	0.0045	0.0047	3.90	3.85	26.43	26.06	
09:55:51	0.255	0.260	0.355	0.375	0.0045	0.0047	3.90	3.85	26.43	26.06	
09:56:51	0.255	0.260	0.355	0.375	0.0045	0.0047	3.90	3.85	26.43	26.06	
09:57:51	0.250	0.260	0.358	0.375	0.0043	0.0047	3.96	3.85	26.82	26.06	
09:58:51	0.250	0.255	0.360	0.373	0.0043	0.0045	3.96	3.90	26.82	26.43	
09:59:51	0.245	0.250	0.363	0.380	0.0040	0.0043	4.02	3.96	27.21	26.82	
10:00:51	0.245	0.250	0.368	0.390	0.0040	0.0043	4.02	3.96	27.21	26.82	
10:01:51	0.245	0.250	0.363	0.383	0.0040	0.0043	4.02	3.96	27.21	26.82	
10:02:51	0.245	0.250	0.365	0.408	0.0040	0.0043	4.02	3.96	27.21	26.82	
10:03:51	0.245	0.250	0.370	0.433	0.0040	0.0043	4.02	3.96	27.21	26.82	
10:04:51	0.245	0.250	0.360	0.405	0.0040	0.0043	4.02	3.96	27.21	26.82	
10:05:51	0.250	0.255	0.350	0.378	0.0043	0.0045	3.96	3.90	26.82	26.43	
10:06:51	0.250	0.260	0.355	0.375	0.0043	0.0047	3.96	3.85	26.82	26.06	

APPENDIX D

D - 8

AUXILIARY VENTILATION SURVEY AT HEADING #9

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1 93m Outbye		CSE #3 AT FACE		CH_4 Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)[&&]	
Time	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max
(hr.)	(%)	(%)	(%)	(%)	$Q_{CH4\ (Avg.)}$	$Q_{CH4\ (Max.)}$	(min)	(min)	(m^3/s)	(m^3/s)
10:07:51	0.250	0.255	0.363	0.385	0.0043	0.0045	3.96	3.90	26.82	26.43
10:08:51	0.245	0.250	0.363	0.393	0.0040	0.0043	4.02	3.96	27.21	26.82
10:09:51	0.240	0.245	0.363	0.388	0.0038	0.0040	4.08	4.02	27.61	27.21
10:10:51	0.240	0.245	0.358	0.380	0.0038	0.0040	4.08	4.02	27.61	27.21
10:11:51	0.240	0.245	0.358	0.390	0.0038	0.0040	4.08	4.02	27.61	27.21
10:12:51	0.240	0.245	0.353	0.385	0.0038	0.0040	4.08	4.02	27.61	27.21
10:13:51	0.240	0.245	0.343	0.365	0.0038	0.0040	4.08	4.02	27.61	27.21
10:14:51	0.240	0.245	0.350	0.380	0.0038	0.0040	4.08	4.02	27.61	27.21
10:15:51	0.240	0.250	0.355	0.380	0.0038	0.0043	4.08	3.96	27.61	26.82
10:16:51	0.240	0.245	0.343	0.355	0.0038	0.0040	4.08	4.02	27.61	27.21
10:17:51	0.245	0.250	0.343	0.365	0.0040	0.0043	4.02	3.96	27.21	26.82
10:18:51	0.240	0.250	0.350	0.383	0.0038	0.0043	4.08	3.96	27.61	26.82
10:19:51	0.240	0.240	0.345	0.373	0.0038	0.0038	4.08	4.08	27.61	27.61
10:20:51	0.240	0.245	0.335	0.355	0.0038	0.0040	4.08	4.02	27.61	27.21
10:21:51	0.240	0.245	0.333	0.353	0.0038	0.0040	4.08	4.02	27.61	27.21
10:22:51	0.235	0.240	0.333	0.355	0.0036	0.0038	4.14	4.08	28.01	27.61
10:23:51	0.240	0.240	0.325	0.345	0.0038	0.0038	4.08	4.08	27.61	27.61

APPENDIX D

D - 9

AUXILIARY VENTILATION SURVEY AT HEADING #9

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1 93m Outbye		CSE #3 AT FACE		CH_4 Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)[&&]	
Time	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max
(hr.)	(%)	(%)	(%)	(%)	$Q_{CH4\,(Avg.)}$	$Q_{CH4\,(Max.)}$	(min)	(min)	(m^3/s)	(m^3/s)
10:24:51	0.240	0.240	0.328	0.360	0.0038	0.0038	4.08	4.08	27.61	27.61
10:25:51	0.245	0.250	0.323	0.355	0.0040	0.0043	4.02	3.96	27.21	26.82
10:26:51	0.250	0.260	0.320	0.338	0.0043	0.0047	3.96	3.85	26.82	26.06
10:27:51	0.250	0.260	0.330	0.348	0.0043	0.0047	3.96	3.85	26.82	26.06
10:28:51	0.235	0.245	0.330	0.360	0.0036	0.0040	4.14	4.02	28.01	27.21
10:29:51	0.230	0.235	0.335	0.378	0.0033	0.0036	4.20	4.14	28.43	28.01
10:30:51	0.230	0.240	0.330	0.360	0.0033	0.0038	4.20	4.08	28.43	27.61
10:31:51	0.230	0.235	0.323	0.343	0.0033	0.0036	4.20	4.14	28.43	28.01
10:32:51	0.235	0.240	0.318	0.343	0.0036	0.0038	4.14	4.08	28.01	27.61
10:33:51	0.235	0.240	0.318	0.360	0.0036	0.0038	4.14	4.08	28.01	27.61
10:34:51	0.230	0.240	0.318	0.355	0.0033	0.0038	4.20	4.08	28.43	27.61
10:35:51	0.235	0.240	0.318	0.340	0.0036	0.0038	4.14	4.08	28.01	27.61
10:36:51	0.230	0.240	0.333	0.350	0.0033	0.0038	4.20	4.08	28.43	27.61
10:37:51	0.235	0.240	0.333	0.343	0.0036	0.0038	4.14	4.08	28.01	27.61
10:38:51	0.230	0.240	0.330	0.353	0.0033	0.0038	4.20	4.08	28.43	27.61
10:39:51	0.235	0.240	0.328	0.355	0.0036	0.0038	4.14	4.08	28.01	27.61
10:40:51	0.240	0.240	0.328	0.345	0.0038	0.0038	4.08	4.08	27.61	27.61

APPENDIX D

D - 10

AUXILIARY VENTILATION SURVEY AT HEADING #9

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1 93m Outbye		CSE #3 AT FACE		CH_4 Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)[&&]	
Time	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max
(hr.)	(%)	(%)	(%)	(%)	$Q_{CH4\ (Avg.)}$	$Q_{CH4\ (Max.)}$	(min)	(min)	(m^3/s)	(m^3/s)
10:41:51	0.240	0.240	0.338	0.365	0.0038	0.0038	4.08	4.08	27.61	27.61
10:42:51	0.240	0.245	0.340	0.380	0.0038	0.0040	4.08	4.02	27.61	27.21
10:43:51	0.245	0.250	0.348	0.378	0.0040	0.0043	4.02	3.96	27.21	26.82
10:44:51	0.250	0.260	0.355	0.375	0.0043	0.0047	3.96	3.85	26.82	26.06
10:45:51	0.255	0.260	0.358	0.380	0.0045	0.0047	3.90	3.85	26.43	26.06
10:46:51	0.255	0.260	0.358	0.383	0.0045	0.0047	3.90	3.85	26.43	26.06
10:47:51	0.260	0.275	0.358	0.380	0.0047	0.0055	3.85	3.69	26.06	24.97
10:48:51	0.285	0.290	0.363	0.385	0.0060	0.0063	3.59	3.54	24.28	23.95
10:49:51	0.280	0.285	0.360	0.380	0.0058	0.0060	3.64	3.59	24.62	24.28
10:50:51	0.275	0.280	0.355	0.370	0.0055	0.0058	3.69	3.64	24.97	24.62
10:51:51	0.275	0.280	0.355	0.373	0.0055	0.0058	3.69	3.64	24.97	24.62
10:52:51	0.275	0.280	0.345	0.368	0.0055	0.0058	3.69	3.64	24.97	24.62
10:53:51	0.270	0.275	0.333	0.353	0.0053	0.0055	3.74	3.69	25.33	24.97
10:54:51	0.260	0.270	0.360	0.385	0.0047	0.0053	3.85	3.74	26.06	25.33
10:55:51	0.260	0.265	0.405	0.440	0.0047	0.0050	3.85	3.79	26.06	25.69
10:56:51	0.265	0.265	0.390	0.435	0.0050	0.0050	3.79	3.79	25.69	25.69
10:57:51	0.265	0.270	0.345	0.383	0.0050	0.0053	3.79	3.74	25.69	25.33

APPENDIX D

D - 11

AUXILIARY VENTILATION SURVEY AT HEADING #9

	CORRELATED TIMES						PURE METHANE CONCENTRATION			
	CSE #1 93m Outbye		CSE #3 AT FACE		CH_4 Lib. Rate (M2)		Purging Time		Purging Qnty. (1 min.)$^{\&\&}$	
Time	Average	Maximum	Average	Maximum	(m^3/s)		Average	Max	Average	Max
(hr.)	(%)	(%)	(%)	(%)	$Q_{CH4\,(Avg.)}$	$Q_{CH4\,(Max.)}$	(min)	(min)	(m^3/s)	(m^3/s)
10:58:51	0.260	0.265	0.338	0.360	0.0047	0.0050	3.85	3.79	26.06	25.69
10:59:51	0.260	0.270	0.340	0.370	0.0047	0.0053	3.85	3.74	26.06	25.33
11:00:51	0.260	0.270	0.350	0.380	0.0047	0.0053	3.85	3.74	26.06	25.33
11:01:51	0.255	0.265	0.375	0.443	0.0045	0.0050	3.90	3.79	26.43	25.69
11:02:51	0.255	0.260	0.375	0.448	0.0045	0.0047	3.90	3.85	26.43	26.06
11:03:51	0.250	0.255	0.360	0.390	0.0043	0.0045	3.96	3.90	26.82	26.43
11:04:51	0.250	0.250	0.373	0.410	0.0043	0.0043	3.96	3.96	26.82	26.82
11:05:51	0.250	0.255	0.373	0.408	0.0043	0.0045	3.96	3.90	26.82	26.43
11:06:51	0.255	0.260	0.340	0.360	0.0045	0.0047	3.90	3.85	26.43	26.06
11:07:51	0.115	0.255	0.323	0.343	-0.0013	0.0045	6.18	3.90	41.84	26.43
Averages	0.26	0.27	0.39	0.43	0.01	0.01	3.84	3.73	26.03	25.24
Standard Dev.	0.04	0.04	0.07	0.09	0.00	0.00	0.44	0.43	2.98	2.90

&& - Dilution from face monitor concentration to Outbye air concentration in 1 minute

- Dilution from Pure methane concentration at the face to Outbye air concentration in 1 minute

APPENDIX D									D - 12	
AUXILIARY VENTILATION SURVEY AT HEADING #9										
		PURE CH_4 CONC.		MONITORS						
	Actual	Effic. of System##		Purging Time&&		Purging Qnty. (1 min.)		Effic. of System&&		
Time	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum	
(hr.)	(m^3/s)	(%)	(%)	(min)	(min)	(m^3/s)	(m^3/s)	(%)	(%)	
8:15:51	6.77	21.75	22.09	3.80	4.29	14.58	16.46	46.45	41.15	
8:16:51	6.77	21.42	21.75	3.84	4.03	14.73	15.47	45.99	43.78	
8:17:51	6.77	21.75	22.09	3.04	3.11	11.64	11.94	58.20	56.73	
8:18:51	6.77	21.42	22.09	3.40	3.40	13.03	13.05	51.97	51.89	
8:19:51	6.77	21.08	21.75	3.82	3.95	14.64	15.14	46.26	44.73	
8:20:51	6.77	21.08	21.42	3.76	4.11	14.40	15.74	47.03	43.02	
8:21:51	6.77	21.08	21.75	3.97	4.15	15.23	15.90	44.47	42.59	
8:22:51	6.77	23.12	25.62	2.89	2.95	11.07	11.31	61.15	59.90	
8:23:51	6.77	24.89	25.99	1.19	1.78	4.55	6.82	148.78	99.23	
8:24:51	6.77	23.12	25.25	2.49	2.33	9.56	8.94	70.84	75.75	
8:25:51	6.77	23.82	25.99	1.13	2.24	4.32	8.57	156.90	78.99	
8:26:51	6.77	27.89	34.74	0.78	2.07	2.98	7.93	227.12	85.39	
8:27:51	6.77	27.89	30.73	0.66	1.72	2.54	6.59	266.57	102.69	
8:28:51	6.77	24.53	25.99	1.00	1.13	3.83	4.32	176.98	156.90	
8:29:51	6.77	23.47	24.53	1.15	1.49	4.40	5.72	153.84	118.49	
8:30:51	6.77	23.47	24.53	1.24	1.61	4.74	6.16	142.83	109.94	

APPENDIX D

D - 13

AUXILIARY VENTILATION SURVEY AT HEADING #9

				MONITORS					
Time	Actual	Effic. of System		Purging Time		Purging Qnty. (1 min.)		Effic. of System	
(hr.)	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum
8:31:51	6.77	24.18	26.74	1.10	1.20	4.23	4.60	159.95	147.20
8:32:51	6.77	29.89	39.81	2.15	2.76	8.25	10.59	82.04	63.95
8:33:51	6.77	40.92	46.37	2.69	4.06	10.33	15.55	65.55	43.56
8:34:51	6.77	42.06	46.37	2.24	3.18	8.57	12.19	79.02	55.57
8:35:51	6.77	35.21	40.36	3.36	3.50	12.88	13.41	52.59	50.51
8:36:51	6.77	32.90	35.21	2.71	3.25	10.38	12.47	65.25	54.31
8:37:51	6.77	32.01	34.27	1.52	2.09	5.82	8.02	116.45	84.43
8:38:51	6.77	27.12	29.48	2.51	2.81	9.63	10.78	70.30	62.83
8:39:51	6.77	24.53	25.99	2.91	3.85	11.17	14.76	60.64	45.90
8:40:51	6.77	23.82	24.18	2.43	3.98	9.33	15.27	72.61	44.35
8:41:51	6.77	24.18	25.99	2.05	2.82	7.84	10.83	86.35	62.56
8:42:51	6.77	29.48	33.35	1.04	1.46	4.00	5.60	169.45	120.95
8:43:51	6.77	36.68	38.21	-0.07	1.00	-0.25	3.83	-2678.27	176.98
8:44:51	6.77	30.73	34.74	0.59	1.43	2.28	5.50	297.25	123.17
8:45:51	6.77	28.28	28.68	0.61	1.57	2.35	6.01	287.90	112.68
8:46:51	6.77	27.50	29.08	0.63	0.74	2.43	2.84	278.55	238.20
8:47:51	6.77	24.89	26.74	2.56	3.11	9.81	11.93	69.00	56.75

APPENDIX D

D - 14

AUXILIARY VENTILATION SURVEY AT HEADING #9

				MONITORS					
	Actual	Effic. of System		Purging Time		Purging Qnty. (1 min.)&&		Effic. of System	
Time	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum
(hr.)	(m^3/s)	(%)	(%)	(min)	(min)	(m^3/s)	(m^3/s)	(%)	(%)
8:48:51	6.77	25.25	27.50	1.91	1.74	7.32	6.66	92.51	101.75
8:49:51	6.77	26.36	27.50	1.98	2.05	7.60	7.84	89.13	86.35
8:50:51	6.77	24.89	25.25	2.95	3.47	11.33	13.31	59.79	50.88
8:51:51	6.77	24.53	25.25	3.78	4.11	14.50	15.77	46.69	42.94
8:52:51	6.77	24.18	24.53	4.20	4.45	16.09	17.07	42.08	39.68
8:53:51	6.77	24.89	25.25	3.72	4.18	14.28	16.03	47.44	42.26
8:54:51	6.77	24.53	24.89	3.28	3.94	12.58	15.11	53.81	44.83
8:55:51	6.77	24.53	24.89	2.97	3.52	11.39	13.51	59.45	50.14
8:56:51	6.77	24.89	25.62	2.69	2.87	10.31	10.99	65.68	61.64
8:57:51	6.77	25.99	26.36	2.30	2.67	8.81	10.24	76.87	66.12
8:58:51	6.77	25.62	26.36	2.78	3.30	10.66	12.66	63.52	53.48
8:59:51	6.77	24.89	25.25	3.15	3.84	12.08	14.72	56.06	46.02
9:00:51	6.77	24.89	25.25	3.15	3.84	12.08	14.72	56.06	46.02
9:01:51	6.77	24.53	24.89	3.52	4.08	13.51	15.64	50.13	43.29
9:02:51	6.77	24.53	24.89	3.06	3.52	11.73	13.51	57.76	50.14
9:03:51	6.77	24.53	24.89	2.70	3.01	10.36	11.54	65.38	58.66

APPENDIX D

D - 15

AUXILIARY VENTILATION SURVEY AT HEADING #9

				MONITORS					
	Actual	Effic. of System		Purging Time		Purging Qnty. (1 min.)$^{\&\&}$		Effic. of System	
Time	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum
(hr.)	(m^3/s)	(%)	(%)	(min)	(min)	(m^3/s)	(m^3/s)	(%)	(%)
9:04:51	6.77	24.53	24.89	3.00	3.31	11.50	12.70	58.87	53.31
9:05:51	6.77	24.89	25.62	2.81	2.98	10.77	11.41	62.89	59.34
9:06:51	6.77	25.99	26.74	2.65	2.82	10.18	10.83	66.55	62.56
9:07:51	6.77	26.74	27.50	2.52	2.87	9.67	11.02	70.07	61.45
9:08:51	6.77	27.50	28.28	2.26	2.54	8.66	9.75	78.25	69.48
9:09:51	6.77	29.08	29.48	1.93	2.16	7.41	8.28	91.41	81.77
9:10:51	6.77	29.48	29.89	1.91	2.18	7.31	8.36	92.68	81.04
9:11:51	6.77	29.89	30.73	1.71	1.97	6.55	7.54	103.35	89.84
9:12:51	6.77	30.73	31.15	1.49	1.75	5.72	6.72	118.49	100.78
9:13:51	6.77	30.73	31.15	1.86	2.05	7.12	7.84	95.05	86.35
9:14:51	6.77	31.15	32.01	1.91	2.00	7.34	7.65	92.26	88.53
9:15:51	6.77	31.58	31.58	1.65	1.89	6.32	7.25	107.17	93.44
9:16:51	6.77	31.58	32.45	1.65	1.79	6.32	6.87	107.17	98.56
9:17:51	6.77	31.58	32.45	1.68	1.84	6.42	7.07	105.41	95.80
9:18:51	6.77	32.01	32.45	1.54	1.77	5.92	6.77	114.35	100.02

APPENDIX D

D - 16

AUXILIARY VENTILATION SURVEY AT HEADING #9

				MONITORS					
	Actual	Effic. of System		Purging Time		Purging Qnty. (1 min.)[&&]		Effic. of System	
Time	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum
(hr.)	(m^3/s)	(%)	(%)	(min)	(min)	(m^3/s)	(m^3/s)	(%)	(%)
9:19:51	6.77	32.01	32.45	1.57	1.87	6.03	7.17	112.34	94.48
9:20:51	6.77	31.58	32.01	1.59	1.81	6.11	6.96	110.90	97.34
9:21:51	6.77	31.15	31.58	1.59	1.70	6.08	6.53	111.41	103.72
9:22:51	6.77	31.15	31.58	1.61	1.73	6.19	6.63	109.46	102.09
9:23:51	6.77	31.15	31.15	1.64	1.78	6.29	6.82	107.59	99.23
9:24:51	6.77	30.73	31.15	1.66	1.75	6.38	6.72	106.17	100.78
9:25:51	6.77	30.73	30.73	1.66	1.94	6.38	7.44	106.17	91.08
9:26:51	6.77	30.31	30.73	1.80	1.97	6.90	7.54	98.16	89.84
9:27:51	6.77	29.48	30.31	1.91	2.05	7.31	7.84	92.68	86.35
9:28:51	6.77	30.31	30.73	1.66	1.97	6.35	7.54	106.58	89.84
9:29:51	6.77	29.48	30.73	1.71	1.89	6.55	7.23	103.33	93.68
9:30:51	6.77	29.08	29.89	1.79	1.99	6.85	7.63	98.85	88.71
9:31:51	6.77	29.48	30.73	1.61	1.69	6.19	6.49	109.43	104.40
9:32:51	6.77	30.73	31.15	1.16	1.53	4.44	5.86	152.64	115.57
9:33:51	6.77	30.73	30.73	0.93	1.28	3.58	4.91	189.33	137.88
9:34:51	6.77	29.48	30.73	0.91	0.97	3.47	3.70	194.95	182.92

APPENDIX D

D - 17

AUXILIARY VENTILATION SURVEY AT HEADING #9

				MONITORS					
	Actual	Effic. of System		Purging Time		Purging Qnty. (1 min.)&&		Effic. of System	
Time	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum
(hr.)	(m^3/s)	(%)	(%)	(min)	(min)	(m^3/s)	(m^3/s)	(%)	(%)
9:35:51	6.77	29.08	29.48	0.99	1.30	3.79	5.00	178.52	135.40
9:36:51	6.77	28.28	28.68	1.23	1.81	4.71	6.95	143.71	97.46
9:37:51	6.77	27.50	28.28	1.27	1.69	4.86	6.46	139.31	104.82
9:38:51	6.77	27.50	27.89	1.13	1.28	4.32	4.92	156.90	137.71
9:39:51	6.77	27.50	27.89	1.20	1.42	4.59	5.44	147.52	124.56
9:40:51	6.77	27.12	27.50	1.29	1.57	4.94	6.03	137.11	112.24
9:41:51	6.77	27.50	27.89	1.16	1.42	4.45	5.44	152.05	124.56
9:42:51	6.77	27.50	27.89	1.16	1.32	4.45	5.05	152.05	134.13
9:43:51	6.77	27.12	27.50	1.18	1.34	4.53	5.13	149.62	132.06
9:44:51	6.77	26.36	26.74	1.37	1.66	5.24	6.35	129.17	106.58
9:45:51	6.77	25.99	26.36	1.57	1.92	6.02	7.35	112.42	92.14
9:46:51	6.77	25.25	25.62	1.84	2.14	7.05	8.22	96.01	82.40
9:47:51	6.77	25.25	25.62	1.87	2.08	7.19	7.97	94.22	84.98
9:48:51	6.77	25.25	25.62	1.87	2.05	7.19	7.84	94.22	86.35
9:49:51	6.77	25.25	25.62	1.94	2.27	7.45	8.71	90.87	77.77
9:50:51	6.77	25.62	25.99	1.84	2.08	7.07	7.97	95.80	85.01

APPENDIX D

D - 18

AUXILIARY VENTILATION SURVEY AT HEADING #9

				MONITORS					
	Actual	Effic. of System		Purging Time		Purging Qnty. (1 min.)$^{\&\&}$		Effic. of System	
Time	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum
(hr.)	(m^3/s)	(%)	(%)	(min)	(min)	(m^3/s)	(m^3/s)	(%)	(%)
9:51:51	6.77	25.62	25.99	1.84	1.98	7.07	7.59	95.80	89.18
9:52:51	6.77	25.62	25.99	2.01	2.42	7.72	9.28	87.77	73.00
9:53:51	6.77	25.62	25.99	1.99	2.42	7.61	9.28	88.94	73.00
9:54:51	6.77	25.62	25.99	1.77	2.01	6.80	7.72	99.53	87.74
9:55:51	6.77	25.62	25.99	1.67	1.85	6.40	7.08	105.82	95.59
9:56:51	6.77	25.62	25.99	1.67	1.85	6.40	7.08	105.82	95.59
9:57:51	6.77	25.25	25.99	1.80	1.85	6.92	7.08	97.88	95.59
9:58:51	6.77	25.25	25.62	1.84	1.91	7.05	7.33	96.01	92.38
9:59:51	6.77	24.89	25.25	1.98	2.11	7.58	8.10	89.37	83.62
10:00:51	6.77	24.89	25.25	2.05	2.24	7.84	8.60	86.35	78.73
10:01:51	6.77	24.89	25.25	1.98	2.15	7.58	8.23	89.37	82.33
10:02:51	6.77	24.89	25.25	2.01	2.47	7.71	9.45	87.83	71.66
10:03:51	6.77	24.89	25.25	2.08	2.77	7.97	10.60	84.93	63.87
10:04:51	6.77	24.89	25.25	1.94	2.43	7.44	9.33	90.97	72.57
10:05:51	6.77	25.25	25.62	1.70	1.98	6.51	7.59	104.05	89.24
10:06:51	6.77	25.25	25.99	1.77	1.85	6.78	7.08	99.84	95.59

APPENDIX D

D - 19

AUXILIARY VENTILATION SURVEY AT HEADING #9

				MONITORS					
	Actual	Effic. of System$^{\&\&}$		Purging Time		Purging Qnty. (1 min.)$^{\&\&}$		Effic. of System	
Time	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum
(hr.)	(m^3/s)	(%)	(%)	(min)	(min)	(m^3/s)	(m^3/s)	(%)	(%)
10:07:51	6.77	25.25	25.62	1.87	2.08	7.19	7.97	94.22	84.98
10:08:51	6.77	24.89	25.25	1.98	2.28	7.58	8.73	89.37	77.62
10:09:51	6.77	24.53	24.89	2.09	2.32	8.00	8.89	84.61	76.15
10:10:51	6.77	24.53	24.89	2.01	2.21	7.71	8.49	87.86	79.77
10:11:51	6.77	24.53	24.89	2.01	2.35	7.71	8.99	87.86	75.31
10:12:51	6.77	24.53	24.89	1.94	2.28	7.44	8.74	91.08	77.46
10:13:51	6.77	24.53	24.89	1.79	2.01	6.88	7.71	98.45	87.83
10:14:51	6.77	24.53	24.89	1.90	2.21	7.30	8.49	92.79	79.77
10:15:51	6.77	24.53	25.25	1.98	2.11	7.57	8.10	89.43	83.62
10:16:51	6.77	24.53	24.89	1.79	1.87	6.88	7.17	98.45	94.40
10:17:51	6.77	24.89	25.25	1.69	1.91	6.48	7.32	104.50	92.51
10:18:51	6.77	24.53	25.25	1.90	2.15	7.30	8.23	92.79	82.33
10:19:51	6.77	24.53	24.53	1.83	2.22	7.02	8.50	96.47	79.64
10:20:51	6.77	24.53	24.89	1.68	1.87	6.45	7.17	104.98	94.40
10:21:51	6.77	24.53	24.89	1.64	1.84	6.31	7.04	107.39	96.24
10:22:51	6.77	24.18	24.53	1.75	1.98	6.71	7.57	100.88	89.43
10:23:51	6.77	24.53	24.53	1.53	1.83	5.86	7.02	115.48	96.47

APPENDIX D

D - 20

AUXILIARY VENTILATION SURVEY AT HEADING #9

				MONITORS					
	Actual	Effic. of System		Purging Time		Purging Qnty. (1 min.)$^{\&\&}$		Effic. of System	
Time	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum
(hr.)	(m^3/s)	(%)	(%)	(min)	(min)	(m^3/s)	(m^3/s)	(%)	(%)
10:24:51	6.77	24.53	24.53	1.57	2.05	6.01	7.84	112.63	86.35
10:25:51	6.77	24.89	25.25	1.39	1.77	5.32	6.78	127.38	99.84
10:26:51	6.77	25.25	25.99	1.25	1.32	4.78	5.05	141.82	134.20
10:27:51	6.77	25.25	25.99	1.40	1.46	5.37	5.61	126.10	120.69
10:28:51	6.77	24.18	24.89	1.71	1.94	6.57	7.44	103.12	90.97
10:29:51	6.77	23.82	24.18	1.90	2.39	7.27	9.17	93.10	73.86
10:30:51	6.77	23.82	24.53	1.82	2.05	6.98	7.84	96.98	86.35
10:31:51	6.77	23.82	24.18	1.71	1.90	6.54	7.29	103.57	92.94
10:32:51	6.77	24.18	24.53	1.52	1.79	5.82	6.88	116.36	98.45
10:33:51	6.77	24.18	24.53	1.52	2.05	5.82	7.84	116.36	86.35
10:34:51	6.77	23.82	24.53	1.63	1.98	6.24	7.57	108.59	89.43
10:35:51	6.77	24.18	24.53	1.52	1.76	5.82	6.74	116.36	100.52
10:36:51	6.77	23.82	24.53	1.86	1.90	7.13	7.30	94.99	92.79
10:37:51	6.77	24.18	24.53	1.75	1.79	6.71	6.88	100.88	98.45
10:38:51	6.77	23.82	24.53	1.82	1.94	6.98	7.44	96.98	91.08
10:39:51	6.77	24.18	24.53	1.67	1.98	6.42	7.57	105.48	89.43
10:40:51	6.77	24.53	24.53	1.57	1.83	6.01	7.02	112.63	96.47

APPENDIX D									D - 21
AUXILIARY VENTILATION SURVEY AT HEADING #9									
				MONITORS					
	Actual	Effic. of System		Purging Time		Purging Qnty. (1 min.)$^{\&\&}$		Effic. of System	
Time	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum
(hr.)	(m^3/s)	(%)	(%)	(min)	(min)	(m^3/s)	(m^3/s)	(%)	(%)
10:41:51	6.77	24.53	24.53	1.72	2.12	6.59	8.11	102.69	83.51
10:42:51	6.77	24.53	24.89	1.76	2.21	6.74	8.49	100.52	79.77
10:43:51	6.77	24.89	25.25	1.76	2.08	6.76	7.97	100.17	84.95
10:44:51	6.77	25.25	25.99	1.77	1.85	6.78	7.08	99.84	95.59
10:45:51	6.77	25.62	25.99	1.70	1.91	6.54	7.34	103.62	92.26
10:46:51	6.77	25.62	25.99	1.70	1.95	6.54	7.47	103.62	90.69
10:47:51	6.77	25.99	27.12	1.61	1.63	6.16	6.26	109.94	108.26
10:48:51	6.77	27.89	28.28	1.21	1.43	4.65	5.48	145.55	123.55
10:49:51	6.77	27.50	27.89	1.27	1.45	4.86	5.56	139.31	121.70
10:50:51	6.77	27.12	27.50	1.29	1.41	4.94	5.39	137.11	125.61
10:51:51	6.77	27.12	27.50	1.29	1.44	4.94	5.52	137.11	122.65
10:52:51	6.77	27.12	27.50	1.14	1.37	4.39	5.26	154.39	128.75
10:53:51	6.77	26.74	27.12	1.05	1.25	4.03	4.80	168.14	141.01
10:54:51	6.77	25.99	26.74	1.64	1.79	6.29	6.86	107.59	98.67
10:55:51	6.77	25.99	26.36	2.24	2.56	8.57	9.81	78.99	69.05
10:56:51	6.77	26.36	26.36	1.95	2.50	7.47	9.59	90.60	70.64
10:57:51	6.77	26.36	26.74	1.33	1.76	5.10	6.74	132.71	100.52

APPENDIX D

D - 22

AUXILIARY VENTILATION SURVEY AT HEADING #9

				MONITORS					
	Actual	Effic. of System		Purging Time		Purging Qnty. (1 min.)&&		Effic. of System	
Time	Quantity	Average	Maximum	Average	Max	Average	Maximum	Average	Maximum
(hr.)	(m^3/s)	(%)	(%)	(min)	(min)	(m^3/s)	(m^3/s)	(%)	(%)
10:58:51	6.77	25.99	26.36	1.32	1.55	5.05	5.93	134.20	114.27
10:59:51	6.77	25.99	26.74	1.35	1.59	5.19	6.09	130.51	111.12
11:00:51	6.77	25.99	26.74	1.50	1.72	5.75	6.61	117.78	102.45
11:01:51	6.77	25.62	26.36	1.95	2.59	7.46	9.92	90.78	68.29
11:02:51	6.77	25.62	25.99	1.95	2.74	7.46	10.50	90.78	64.48
11:03:51	6.77	25.25	25.62	1.84	2.14	7.05	8.22	96.01	82.40
11:04:51	6.77	25.25	25.25	2.01	2.50	7.71	9.57	87.80	70.77
11:05:51	6.77	25.25	25.62	2.01	2.37	7.71	9.07	87.80	74.68
11:06:51	6.77	25.62	25.99	1.45	1.64	5.56	6.29	121.70	107.59
11:07:51	6.77	16.19	25.62	5.20	1.49	19.95	5.71	33.95	118.68
Averages		26.38	27.26	1.92	2.22	7.35	8.50	89.19	88.59
Standard Dev.		3.28	3.81	0.77	0.77	2.94	2.97	215.86	28.87

&& - Dilution from face monitor concentration to Outbye air concentration in 1 minute

- Dilution from Pure methane concentration at the face to Outbye air concentration in 1 minute

APPENDIX E

RESULTS OF AUXILIARY VENTILATION SURVEY AT HEADING NUMBER 10

APPENDIX E				E - 1
AUXILIARY VENTILATION SURVEY AT HEADING #10				

		(cfm)	(m³/s)
Intake Air Qnty.		7500	3.54
Exhaust Air Qnty.		7208	3.40
Dist. of duct from face (m)			11
Intake Quantity at face		4043.25	1.91
Volume of Room (Heading) (m3)			861.12

	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
	CSE #1 @ FACE		CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time##		Purging Qnty## (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	(m^3/s)
09:21:50	0.290	0.512	0.098	0.105	-0.0021	-0.0018	9.44	9.14	33.41	32.35
09:22:50	0.260	0.270	0.095	0.105	-0.0022	-0.0018	9.54	9.14	33.78	32.35
09:23:50	0.260	0.270	0.095	0.105	-0.0022	-0.0018	9.54	9.14	33.78	32.35
09:24:50	0.265	0.270	0.115	0.143	-0.0014	-0.0003	8.77	7.90	31.04	27.96
09:25:50	0.270	0.290	0.155	0.185	0.0002	0.0015	7.56	6.84	26.76	24.22
09:26:50	0.315	0.335	0.170	0.185	0.0009	0.0015	7.18	6.84	25.43	24.22
09:27:50	0.365	0.400	0.183	0.203	0.0014	0.0023	6.90	6.48	24.41	22.92
09:28:50	0.440	0.480	0.215	0.248	0.0029	0.0046	6.23	5.66	22.06	20.04
09:29:50	0.505	0.520	0.245	0.270	0.0045	0.0058	5.70	5.31	20.19	18.79
09:30:50	0.515	0.520	0.248	0.268	0.0046	0.0057	5.66	5.35	20.04	18.93
09:31:50	0.500	0.520	0.223	0.245	0.0033	0.0045	6.09	5.70	21.57	20.19

APPENDIX E									E - 2	
AUXILIARY VENTILATION SURVEY AT HEADING #10										
	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
CSE #1 @ FACE			CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
09:32:50	0.470	0.485	0.208	0.220	0.0026	0.0032	6.38	6.14	22.57	21.73
09:33:50	0.440	0.450	0.193	0.203	0.0019	0.0023	6.68	6.48	23.65	22.92
09:34:50	0.430	0.445	0.175	0.185	0.0011	0.0015	7.07	6.84	25.02	24.22
09:35:50	0.405	0.440	0.165	0.180	0.0006	0.0013	7.31	6.95	25.86	24.61
09:36:50	0.385	0.390	0.153	0.173	0.0001	0.0010	7.63	7.13	26.99	25.22
09:37:50	0.365	0.385	0.145	0.163	-0.0002	0.0005	7.83	7.37	27.71	26.08
09:38:50	0.350	0.360	0.145	0.160	-0.0002	0.0004	7.83	7.43	27.71	26.30
09:39:50	0.345	0.355	0.145	0.163	-0.0002	0.0005	7.83	7.37	27.71	26.08
09:40:50	0.335	0.350	0.143	0.158	-0.0003	0.0003	7.90	7.49	27.96	26.53
09:41:50	0.330	0.340	0.140	0.145	-0.0004	-0.0002	7.97	7.83	28.22	27.71
09:42:50	0.320	0.325	0.138	0.140	-0.0005	-0.0004	8.05	7.97	28.48	28.22
09:43:50	0.315	0.325	0.133	0.140	-0.0007	-0.0004	8.20	7.97	29.01	28.22
09:44:50	0.310	0.320	0.128	0.135	-0.0009	-0.0006	8.35	8.12	29.56	28.74
09:45:50	0.300	0.310	0.125	0.133	-0.0010	-0.0007	8.43	8.20	29.84	29.01
09:46:50	0.290	0.300	0.125	0.138	-0.0010	-0.0005	8.43	8.05	29.84	28.48
09:47:50	0.290	0.300	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74
09:48:50	0.290	0.295	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74

APPENDIX E

E - 3

AUXILIARY VENTILATION SURVEY AT HEADING #10

	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
CSE #1 @ FACE			CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
09:49:50	0.290	0.295	0.123	0.135	-0.0011	-0.0006	8.51	8.12	30.13	28.74
09:50:50	0.285	0.295	0.120	0.130	-0.0012	-0.0008	8.60	8.27	30.43	29.28
09:51:50	0.280	0.290	0.123	0.135	-0.0011	-0.0006	8.51	8.12	30.13	28.74
09:52:50	0.280	0.285	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74
09:53:50	0.275	0.285	0.125	0.130	-0.0010	-0.0008	8.43	8.27	29.84	29.28
09:54:50	0.275	0.285	0.125	0.130	-0.0010	-0.0008	8.43	8.27	29.84	29.28
09:55:50	0.275	0.285	0.123	0.130	-0.0011	-0.0008	8.51	8.27	30.13	29.28
09:56:50	0.275	0.280	0.120	0.130	-0.0012	-0.0008	8.60	8.27	30.43	29.28
09:57:50	0.280	0.290	0.123	0.135	-0.0011	-0.0006	8.51	8.12	30.13	28.74
09:58:50	0.270	0.280	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74
09:59:50	0.280	0.295	0.123	0.130	-0.0011	-0.0008	8.51	8.27	30.13	29.28
10:00:50	0.275	0.295	0.120	0.128	-0.0012	-0.0009	8.60	8.35	30.43	29.56
10:01:50	0.265	0.275	0.120	0.125	-0.0012	-0.0010	8.60	8.43	30.43	29.84
10:02:50	0.270	0.275	0.120	0.125	-0.0012	-0.0010	8.60	8.43	30.43	29.84
10:03:50	0.270	0.275	0.120	0.125	-0.0012	-0.0010	8.60	8.43	30.43	29.84
10:04:50	0.265	0.275	0.120	0.125	-0.0012	-0.0010	8.60	8.43	30.43	29.84
10:05:50	0.270	0.280	0.120	0.125	-0.0012	-0.0010	8.60	8.43	30.43	29.84
10:06:50	0.265	0.280	0.120	0.125	-0.0012	-0.0010	8.60	8.43	30.43	29.84

APPENDIX E

E - 4

AUXILIARY VENTILATION SURVEY AT HEADING #10

	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
	CSE #1 @ FACE		CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
10:07:50	0.265	0.280	0.118	0.125	-0.0013	-0.0010	8.68	8.43	30.73	29.84
10:08:50	0.260	0.270	0.115	0.123	-0.0014	-0.0011	8.77	8.51	31.04	30.13
10:09:50	0.260	0.265	0.115	0.120	-0.0014	-0.0012	8.77	8.60	31.04	30.43
10:10:50	0.260	0.270	0.115	0.120	-0.0014	-0.0012	8.77	8.60	31.04	30.43
10:11:50	0.260	0.270	0.113	0.120	-0.0015	-0.0012	8.86	8.60	31.36	30.43
10:12:50	0.265	0.270	0.113	0.125	-0.0015	-0.0010	8.86	8.43	31.36	29.84
10:13:50	0.265	0.275	0.128	0.145	-0.0009	-0.0002	8.35	7.83	29.56	27.71
10:14:50	0.280	0.300	0.153	0.173	0.0001	0.0010	7.63	7.13	26.99	25.22
10:15:50	0.325	0.345	0.173	0.195	0.0010	0.0020	7.13	6.63	25.22	23.46
10:16:50	0.410	0.470	0.198	0.223	0.0021	0.0033	6.58	6.09	23.28	21.57
10:17:50	0.515	0.545	0.203	0.228	0.0023	0.0036	6.48	6.00	22.92	21.25
10:18:50	0.545	0.550	0.193	0.215	0.0019	0.0029	6.68	6.23	23.65	22.06
10:19:50	0.505	0.540	0.198	0.215	0.0021	0.0029	6.58	6.23	23.28	22.06
10:20:50	0.470	0.500	0.193	0.208	0.0019	0.0026	6.68	6.38	23.65	22.57
10:21:50	0.455	0.475	0.183	0.195	0.0014	0.0020	6.90	6.63	24.41	23.46
10:22:50	0.425	0.440	0.178	0.188	0.0012	0.0016	7.01	6.79	24.81	24.02
10:23:50	0.405	0.425	0.180	0.193	0.0013	0.0019	6.95	6.68	24.61	23.65
10:24:50	0.400	0.440	0.193	0.205	0.0019	0.0024	6.68	6.43	23.65	22.74

APPENDIX E

E - 5

AUXILIARY VENTILATION SURVEY AT HEADING #10

	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
	CSE #1 @ FACE		CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
10:25:50	0.410	0.430	0.203	0.213	0.0023	0.0028	6.48	6.28	22.92	22.23
10:26:50	0.410	0.420	0.188	0.198	0.0016	0.0021	6.79	6.58	24.02	23.28
10:27:50	0.405	0.425	0.163	0.175	0.0005	0.0011	7.37	7.07	26.08	25.02
10:28:50	0.370	0.395	0.153	0.165	0.0001	0.0006	7.63	7.31	26.99	25.86
10:29:50	0.370	0.385	0.148	0.160	-0.0001	0.0004	7.76	7.43	27.47	26.30
10:30:50	0.340	0.365	0.143	0.153	-0.0003	0.0001	7.90	7.63	27.96	26.99
10:31:50	0.330	0.340	0.145	0.155	-0.0002	0.0002	7.83	7.56	27.71	26.76
10:32:50	0.325	0.335	0.155	0.165	0.0002	0.0006	7.56	7.31	26.76	25.86
10:33:50	0.325	0.335	0.155	0.165	0.0002	0.0006	7.56	7.31	26.76	25.86
10:34:50	0.320	0.345	0.143	0.155	-0.0003	0.0002	7.90	7.56	27.96	26.76
10:35:50	0.310	0.330	0.133	0.143	-0.0007	-0.0003	8.20	7.90	29.01	27.96
10:36:50	0.300	0.320	0.128	0.135	-0.0009	-0.0006	8.35	8.12	29.56	28.74
10:37:50	0.300	0.320	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74
10:38:50	0.295	0.300	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74
10:39:50	0.295	0.320	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74
10:40:50	0.285	0.300	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74
10:41:50	0.285	0.295	0.125	0.130	-0.0010	-0.0008	8.43	8.27	29.84	29.28
10:42:50	0.290	0.300	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74

APPENDIX E

E - 6

AUXILIARY VENTILATION SURVEY AT HEADING #10

	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
CSE #1 @ FACE		CSE #3 - 69 m Outbye			CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
10:43:50	0.295	0.320	0.128	0.140	-0.0009	-0.0004	8.35	7.97	29.56	28.22
10:44:50	0.280	0.290	0.128	0.135	-0.0009	-0.0006	8.35	8.12	29.56	28.74
10:45:50	0.285	0.295	0.125	0.130	-0.0010	-0.0008	8.43	8.27	29.84	29.28
10:46:50	0.280	0.290	0.123	0.130	-0.0011	-0.0008	8.51	8.27	30.13	29.28
10:47:50	0.285	0.290	0.123	0.130	-0.0011	-0.0008	8.51	8.27	30.13	29.28
10:48:50	0.280	0.290	0.123	0.130	-0.0011	-0.0008	8.51	8.27	30.13	29.28
10:49:50	0.280	0.300	0.120	0.128	-0.0012	-0.0009	8.60	8.35	30.43	29.56
10:50:50	0.270	0.280	0.120	0.125	-0.0012	-0.0010	8.60	8.43	30.43	29.84
10:51:50	0.265	0.280	0.120	0.128	-0.0012	-0.0009	8.60	8.35	30.43	29.56
10:52:50	0.270	0.285	0.120	0.128	-0.0012	-0.0009	8.60	8.35	30.43	29.56
10:53:50	0.265	0.275	0.120	0.125	-0.0012	-0.0010	8.60	8.43	30.43	29.84
10:54:50	0.270	0.280	0.120	0.128	-0.0012	-0.0009	8.60	8.35	30.43	29.56
10:55:50	0.265	0.285	0.120	0.128	-0.0012	-0.0009	8.60	8.35	30.43	29.56
10:56:50	0.265	0.270	0.123	0.133	-0.0011	-0.0007	8.51	8.20	30.13	29.01
10:57:50	0.275	0.290	0.128	0.140	-0.0009	-0.0004	8.35	7.97	29.56	28.22
10:58:50	0.290	0.320	0.128	0.135	-0.0009	-0.0006	8.35	8.12	29.56	28.74
10:59:50	0.285	0.300	0.125	0.130	-0.0010	-0.0008	8.43	8.27	29.84	29.28
11:00:50	0.275	0.280	0.125	0.130	-0.0010	-0.0008	8.43	8.27	29.84	29.28

APPENDIX E

E - 7

AUXILIARY VENTILATION SURVEY AT HEADING #10

	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
	CSE #1 @ FACE		CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
11:01:50	0.275	0.290	0.123	0.128	-0.0011	-0.0009	8.51	8.35	30.13	29.56
11:02:50	0.275	0.300	0.120	0.125	-0.0012	-0.0010	8.60	8.43	30.43	29.84
11:03:50	0.275	0.295	0.118	0.123	-0.0013	-0.0011	8.68	8.51	30.73	30.13
11:04:50	0.270	0.280	0.118	0.123	-0.0013	-0.0011	8.68	8.51	30.73	30.13
11:05:50	0.270	0.285	0.118	0.123	-0.0013	-0.0011	8.68	8.51	30.73	30.13
11:06:50	0.260	0.280	0.118	0.120	-0.0013	-0.0012	8.68	8.60	30.73	30.43
11:07:50	0.270	0.285	0.135	0.145	-0.0006	-0.0002	8.12	7.83	28.74	27.71
11:08:50	0.285	0.305	0.153	0.170	0.0001	0.0009	7.63	7.18	26.99	25.43
11:09:50	0.305	0.320	0.165	0.178	0.0006	0.0012	7.31	7.01	25.86	24.81
11:10:50	0.335	0.360	0.183	0.193	0.0014	0.0019	6.90	6.68	24.41	23.65
11:11:50	0.370	0.390	0.220	0.240	0.0032	0.0042	6.14	5.79	21.73	20.48
11:12:50	0.435	0.470	0.268	0.298	0.0057	0.0074	5.35	4.92	18.93	17.40
11:13:50	0.530	0.550	0.275	0.298	0.0061	0.0074	5.23	4.92	18.53	17.40
11:14:50	0.560	0.570	0.250	0.270	0.0047	0.0058	5.62	5.31	19.90	18.79
11:15:50	0.535	0.565	0.223	0.240	0.0033	0.0042	6.09	5.79	21.57	20.48
11:16:50	0.495	0.525	0.205	0.215	0.0024	0.0029	6.43	6.23	22.74	22.06
11:17:50	0.460	0.480	0.193	0.203	0.0019	0.0023	6.68	6.48	23.65	22.92
11:18:50	0.435	0.460	0.183	0.193	0.0014	0.0019	6.90	6.68	24.41	23.65

APPENDIX E

E - 8

AUXILIARY VENTILATION SURVEY AT HEADING #10

	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
	CSE #1 @ FACE		CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
11:19:50	0.415	0.430	0.175	0.185	0.0011	0.0015	7.07	6.84	25.02	24.22
11:20:50	0.390	0.410	0.168	0.180	0.0007	0.0013	7.24	6.95	25.64	24.61
11:21:50	0.365	0.385	0.165	0.175	0.0006	0.0011	7.31	7.07	25.86	25.02
11:22:50	0.355	0.365	0.165	0.175	0.0006	0.0011	7.31	7.07	25.86	25.02
11:23:50	0.340	0.355	0.165	0.175	0.0006	0.0011	7.31	7.07	25.86	25.02
11:24:50	0.330	0.340	0.150	0.165	0.0000	0.0006	7.69	7.31	27.23	25.86
11:25:50	0.325	0.335	0.123	0.140	-0.0011	-0.0004	8.51	7.97	30.13	28.22
11:26:50	0.345	0.355	0.105	0.113	-0.0018	-0.0015	9.14	8.86	32.35	31.36
11:27:50	0.355	0.370	0.103	0.115	-0.0019	-0.0014	9.24	8.77	32.69	31.04
11:28:50	0.325	0.340	0.113	0.125	-0.0015	-0.0010	8.86	8.43	31.36	29.84
11:29:50	0.290	0.320	0.125	0.133	-0.0010	-0.0007	8.43	8.20	29.84	29.01
11:30:50	0.270	0.280	0.133	0.143	-0.0007	-0.0003	8.20	7.90	29.01	27.96
11:31:50	0.275	0.280	0.135	0.143	-0.0006	-0.0003	8.12	7.90	28.74	27.96
11:32:50	0.275	0.280	0.135	0.140	-0.0006	-0.0004	8.12	7.97	28.74	28.22
11:33:50	0.280	0.285	0.135	0.140	-0.0006	-0.0004	8.12	7.97	28.74	28.22
11:34:50	0.280	0.290	0.135	0.140	-0.0006	-0.0004	8.12	7.97	28.74	28.22
11:35:50	0.280	0.290	0.135	0.140	-0.0006	-0.0004	8.12	7.97	28.74	28.22
11:36:50	0.285	0.290	0.135	0.140	-0.0006	-0.0004	8.12	7.97	28.74	28.22

APPENDIX E									E - 9	
AUXILIARY VENTILATION SURVEY AT HEADING #10										
	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
CSE #1 @ FACE			CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
11:37:50	0.285	0.290	0.133	0.140	-0.0007	-0.0004	8.20	7.97	29.01	28.22
11:38:50	0.280	0.295	0.133	0.143	-0.0007	-0.0003	8.20	7.90	29.01	27.96
11:39:50	0.285	0.290	0.133	0.143	-0.0007	-0.0003	8.20	7.90	29.01	27.96
11:40:50	0.280	0.290	0.128	0.140	-0.0009	-0.0004	8.35	7.97	29.56	28.22
11:41:50	0.275	0.285	0.125	0.140	-0.0010	-0.0004	8.43	7.97	29.84	28.22
11:42:50	0.280	0.290	0.125	0.140	-0.0010	-0.0004	8.43	7.97	29.84	28.22
11:43:50	0.280	0.295	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74
11:44:50	0.280	0.290	0.128	0.135	-0.0009	-0.0006	8.35	8.12	29.56	28.74
11:45:50	0.275	0.285	0.130	0.140	-0.0008	-0.0004	8.27	7.97	29.28	28.22
11:46:50	0.280	0.290	0.130	0.140	-0.0008	-0.0004	8.27	7.97	29.28	28.22
11:47:50	0.280	0.285	0.130	0.140	-0.0008	-0.0004	8.27	7.97	29.28	28.22
11:48:50	0.275	0.280	0.130	0.140	-0.0008	-0.0004	8.27	7.97	29.28	28.22
11:49:50	0.280	0.285	0.130	0.140	-0.0008	-0.0004	8.27	7.97	29.28	28.22
11:50:50	0.275	0.280	0.128	0.135	-0.0009	-0.0006	8.35	8.12	29.56	28.74
11:51:50	0.275	0.280	0.123	0.130	-0.0011	-0.0008	8.51	8.27	30.13	29.28
11:52:50	0.270	0.275	0.120	0.130	-0.0012	-0.0008	8.60	8.27	30.43	29.28
11:53:50	0.270	0.275	0.123	0.130	-0.0011	-0.0008	8.51	8.27	30.13	29.28
11:54:50	0.270	0.275	0.125	0.130	-0.0010	-0.0008	8.43	8.27	29.84	29.28

APPENDIX E **E - 10**

AUXILIARY VENTILATION SURVEY AT HEADING #10

	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
	CSE #1 @ FACE		CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
11:55:50	0.265	0.270	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74
11:56:50	0.270	0.275	0.123	0.135	-0.0011	-0.0006	8.51	8.12	30.13	28.74
11:57:50	0.265	0.270	0.123	0.130	-0.0011	-0.0008	8.51	8.27	30.13	29.28
11:58:50	0.265	0.270	0.123	0.130	-0.0011	-0.0008	8.51	8.27	30.13	29.28
11:59:50	0.260	0.265	0.125	0.138	-0.0010	-0.0005	8.43	8.05	29.84	28.48
12:00:50	0.260	0.270	0.140	0.158	-0.0004	0.0003	7.97	7.49	28.22	26.53
12:01:50	0.275	0.280	0.155	0.170	0.0002	0.0009	7.56	7.18	26.76	25.43
12:02:50	0.280	0.290	0.148	0.155	-0.0001	0.0002	7.76	7.56	27.47	26.76
12:03:50	0.285	0.290	0.135	0.140	-0.0006	-0.0004	8.12	7.97	28.74	28.22
12:04:50	0.285	0.295	0.133	0.140	-0.0007	-0.0004	8.20	7.97	29.01	28.22
12:05:50	0.290	0.300	0.128	0.135	-0.0009	-0.0006	8.35	8.12	29.56	28.74
12:06:50	0.280	0.290	0.128	0.145	-0.0009	-0.0002	8.35	7.83	29.56	27.71
12:07:50	0.275	0.295	0.128	0.150	-0.0009	0.0000	8.35	7.69	29.56	27.23
12:08:50	0.275	0.285	0.125	0.135	-0.0010	-0.0006	8.43	8.12	29.84	28.74
12:09:50	0.265	0.275	0.123	0.130	-0.0011	-0.0008	8.51	8.27	30.13	29.28
12:10:50	0.265	0.275	0.120	0.128	-0.0012	-0.0009	8.60	8.35	30.43	29.56
12:11:50	0.260	0.275	0.120	0.125	-0.0012	-0.0010	8.60	8.43	30.43	29.84
12:12:50	0.265	0.280	0.120	0.123	-0.0012	-0.0011	8.60	8.51	30.43	30.13

APPENDIX E

E - 11

AUXILIARY VENTILATION SURVEY AT HEADING #10

	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
	CSE #1 @ FACE		CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
12:13:50	0.260	0.285	0.115	0.120	-0.0014	-0.0012	8.77	8.60	31.04	30.43
12:14:50	0.260	0.275	0.113	0.120	-0.0015	-0.0012	8.86	8.60	31.36	30.43
12:15:50	0.260	0.275	0.120	0.140	-0.0012	-0.0004	8.60	7.97	30.43	28.22
12:16:50	0.255	0.265	0.133	0.165	-0.0007	0.0006	8.20	7.31	29.01	25.86
12:17:50	0.260	0.270	0.145	0.170	-0.0002	0.0009	7.83	7.18	27.71	25.43
12:18:50	0.255	0.260	0.155	0.173	0.0002	0.0010	7.56	7.13	26.76	25.22
12:19:50	0.260	0.265	0.155	0.168	0.0002	0.0007	7.56	7.24	26.76	25.64
12:20:50	0.260	0.270	0.153	0.165	0.0001	0.0006	7.63	7.31	26.99	25.86
12:21:50	0.265	0.275	0.155	0.170	0.0002	0.0009	7.56	7.18	26.76	25.43
12:22:50	0.255	0.265	0.158	0.175	0.0003	0.0011	7.49	7.07	26.53	25.02
12:23:50	0.255	0.265	0.150	0.173	0.0000	0.0010	7.69	7.13	27.23	25.22
12:24:50	0.280	0.290	0.138	0.168	-0.0005	0.0007	8.05	7.24	28.48	25.64
12:25:50	0.280	0.290	0.138	0.170	-0.0005	0.0009	8.05	7.18	28.48	25.43
12:26:50	0.265	0.280	0.133	0.158	-0.0007	0.0003	8.20	7.49	29.01	26.53
12:27:50	0.250	0.265	0.125	0.153	-0.0010	0.0001	8.43	7.63	29.84	26.99
12:28:50	0.240	0.245	0.130	0.163	-0.0008	0.0005	8.27	7.37	29.28	26.08
12:29:50	0.240	0.245	0.128	0.155	-0.0009	0.0002	8.35	7.56	29.56	26.76
12:30:50	0.245	0.250	0.130	0.165	-0.0008	0.0006	8.27	7.31	29.28	25.86

APPENDIX E									E - 12	
AUXILIARY VENTILATION SURVEY AT HEADING #10										
	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
	CSE #1 @ FACE		CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
12:31:50	0.240	0.250	0.140	0.175	-0.0004	0.0011	7.97	7.07	28.22	25.02
12:32:50	0.240	0.250	0.138	0.165	-0.0005	0.0006	8.05	7.31	28.48	25.86
12:33:50	0.235	0.240	0.133	0.163	-0.0007	0.0005	8.20	7.37	29.01	26.08
12:34:50	0.235	0.240	0.133	0.163	-0.0007	0.0005	8.20	7.37	29.01	26.08
12:35:50	0.240	0.250	0.135	0.165	-0.0006	0.0006	8.12	7.31	28.74	25.86
12:36:50	0.245	0.255	0.138	0.175	-0.0005	0.0011	8.05	7.07	28.48	25.02
12:37:50	0.230	0.240	0.135	0.163	-0.0006	0.0005	8.12	7.37	28.74	26.08
12:38:50	0.235	0.245	0.145	0.168	-0.0002	0.0007	7.83	7.24	27.71	25.64
12:39:50	0.245	0.265	0.170	0.195	0.0009	0.0020	7.18	6.63	25.43	23.46
12:40:50	0.285	0.320	0.200	0.225	0.0022	0.0034	6.53	6.05	23.10	21.41
12:41:50	0.360	0.405	0.245	0.273	0.0045	0.0060	5.70	5.27	20.19	18.66
12:42:50	0.430	0.465	0.270	0.290	0.0058	0.0070	5.31	5.02	18.79	17.77
12:43:50	0.480	0.495	0.253	0.273	0.0049	0.0060	5.58	5.27	19.75	18.66
12:44:50	0.475	0.495	0.225	0.243	0.0034	0.0043	6.05	5.74	21.41	20.33
12:45:50	0.445	0.465	0.215	0.230	0.0029	0.0037	6.23	5.96	22.06	21.09
12:46:50	0.415	0.430	0.208	0.228	0.0026	0.0036	6.38	6.00	22.57	21.25
12:47:50	0.390	0.400	0.195	0.225	0.0020	0.0034	6.63	6.05	23.46	21.41
12:48:50	0.370	0.390	0.185	0.213	0.0015	0.0028	6.84	6.28	24.22	22.23

APPENDIX E									E - 13	
AUXILIARY VENTILATION SURVEY AT HEADING #10										
	CORRELATED TIMES						STRATA CONCENTRATION (PURE)			
	CSE #1 @ FACE		CSE #3 - 69 m Outbye		CH_4 Lib. Rate (M2)		Purging Time[1]		Purging Qnty (1min)	
TIME	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(%)	(%)	(%)	(%)	m^3/s	m^3/s	(min.)	(min.)	m^3/s	m^3/s
12:49:50	0.345	0.360	0.175	0.193	0.0011	0.0019	7.07	6.68	25.02	23.65
12:50:50	0.335	0.340	0.168	0.185	0.0007	0.0015	7.24	6.84	25.64	24.22
12:51:50	0.325	0.340	0.165	0.183	0.0006	0.0014	7.31	6.90	25.86	24.41
12:52:50	0.315	0.320	0.173	0.190	0.0010	0.0017	7.13	6.73	25.22	23.83
12:53:50	0.310	0.320	0.180	0.200	0.0013	0.0022	6.95	6.53	24.61	23.10
12:54:50	0.305	0.320	0.178	0.200	0.0012	0.0022	7.01	6.53	24.81	23.10
12:55:50	0.300	0.320	0.168	0.188	0.0007	0.0016	7.24	6.79	25.64	24.02
12:56:50	0.300	0.325	0.158	0.180	0.0003	0.0013	7.49	6.95	26.53	24.61
12:57:50	0.290	0.305	0.148	0.173	-0.0001	0.0010	7.76	7.13	27.47	25.22
12:58:50	0.290	0.300	0.143	0.160	-0.0003	0.0004	7.90	7.43	27.96	26.30
12:59:50	0.285	0.300	0.140	0.160	-0.0004	0.0004	7.97	7.43	28.22	26.30
13:00:50	0.285	0.300	0.135	0.150	-0.0006	0.0000	8.12	7.69	28.74	27.23
13:01:50	0.275	0.285	0.138	0.150	-0.0005	0.0000	8.05	7.69	28.48	27.23
13:02:50	0.280	0.285	0.140	0.160	-0.0004	0.0004	7.97	7.43	28.22	26.30
13:03:50	0.275	0.290	0.138	0.155	-0.0005	0.0002	8.05	7.56	28.48	26.76
13:04:50	0.270	0.275	0.133	0.158	-0.0007	0.0003	8.20	7.49	29.01	26.53
13:05:50	0.275	0.285	0.125	0.163	-0.0010	0.0005	8.43	7.37	29.84	26.08
Average	0.31	0.33	0.15	0.16	0.00	0.00	7.90	7.54	27.97	26.70
Standard Dev.	0.07	0.08	0.03	0.04	0.00	0.00	0.85	0.88	3.00	3.11
## - Dilution from Pure Methane Concentration at face down to Return Air Concentration										
&& - Dilution from Face Monitor Concentration to Return Air Concentration within 1 minute										

APPENDIX E

E - 14

AUXILIARY VENTILATION SURVEY AT HEADING #10

		MONITOR CONCENTRATION							
	Actual	Effic. of System		Purging Time&&		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(%)	(%)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
09:21:50	3.54	10.59	10.94	4.42	6.42	15.64	22.72	22.63	15.58
09:22:50	3.54	10.48	10.94	4.08	3.83	14.45	13.55	24.50	26.11
09:23:50	3.54	10.48	10.94	4.08	3.83	14.45	13.55	24.50	26.11
09:24:50	3.54	11.40	12.66	3.38	2.59	11.98	9.17	29.54	38.59
09:25:50	3.54	13.23	14.62	2.25	1.82	7.97	6.45	44.44	54.86
09:26:50	3.54	13.92	14.62	2.50	2.41	8.85	8.52	39.99	41.54
09:27:50	3.54	14.50	15.44	2.81	2.76	9.95	9.77	35.58	36.23
09:28:50	3.54	16.04	17.66	2.90	2.69	10.28	9.51	34.44	37.23
09:29:50	3.54	17.53	18.84	2.93	2.66	10.38	9.41	34.10	37.63
09:30:50	3.54	17.66	18.70	2.97	2.70	10.52	9.54	33.66	37.10
09:31:50	3.54	16.41	17.53	3.28	3.05	11.62	10.80	30.46	32.77
09:32:50	3.54	15.68	16.29	3.32	3.21	11.73	11.35	30.16	31.20
09:33:50	3.54	14.97	15.44	3.35	3.24	11.86	11.46	29.83	30.89
09:34:50	3.54	14.15	14.62	3.65	3.56	12.90	12.60	27.43	28.10
09:35:50	3.54	13.69	14.38	3.64	3.62	12.89	12.83	27.47	27.59
09:36:50	3.54	13.11	14.03	3.75	3.31	13.29	11.71	26.63	30.23
09:37:50	3.54	12.77	13.57	3.74	3.50	13.25	12.38	26.72	28.59
09:38:50	3.54	12.77	13.46	3.57	3.29	12.65	11.64	27.99	30.41

APPENDIX E

E - 15

AUXILIARY VENTILATION SURVEY AT HEADING #10

				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
09:39:50	3.54	12.77	13.57	3.51	3.17	12.44	11.22	28.45	31.56
09:40:50	3.54	12.66	13.34	3.47	3.24	12.27	11.46	28.85	30.89
09:41:50	3.54	12.54	12.77	3.48	3.46	12.31	12.23	28.76	28.94
09:42:50	3.54	12.43	12.54	3.42	3.41	12.12	12.09	29.20	29.28
09:43:50	3.54	12.20	12.54	3.51	3.41	12.43	12.09	28.48	29.28
09:44:50	3.54	11.97	12.32	3.60	3.50	12.75	12.39	27.76	28.58
09:45:50	3.54	11.86	12.20	3.55	3.45	12.56	12.20	28.17	29.02
09:46:50	3.54	11.86	12.43	3.41	3.16	12.08	11.20	29.31	31.61
09:47:50	3.54	11.86	12.32	3.41	3.24	12.08	11.46	29.31	30.89
09:48:50	3.54	11.86	12.32	3.41	3.17	12.08	11.22	29.31	31.55
09:49:50	3.54	11.75	12.32	3.49	3.17	12.37	11.22	28.62	31.55
09:50:50	3.54	11.63	12.09	3.51	3.32	12.41	11.76	28.51	30.10
09:51:50	3.54	11.75	12.32	3.35	3.10	11.86	10.97	29.83	32.26
09:52:50	3.54	11.86	12.32	3.27	3.03	11.57	10.72	30.58	33.01
09:53:50	3.54	11.86	12.09	3.20	3.18	11.32	11.27	31.28	31.42
09:54:50	3.54	11.86	12.09	3.20	3.18	11.32	11.27	31.28	31.42
09:55:50	3.54	11.75	12.09	3.28	3.18	11.61	11.27	30.50	31.42
09:56:50	3.54	11.63	12.09	3.36	3.11	11.90	11.01	29.74	32.14
09:57:50	3.54	11.75	12.32	3.35	3.10	11.86	10.97	29.83	32.26
09:58:50	3.54	11.86	12.32	3.12	2.96	11.05	10.47	32.03	33.81
09:59:50	3.54	11.75	12.09	3.35	3.32	11.86	11.76	29.83	30.10

APPENDIX E

E - 16

AUXILIARY VENTILATION SURVEY AT HEADING #10

				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
10:00:50	3.54	11.63	11.97	3.36	3.40	11.90	12.04	29.74	29.40
10:01:50	3.54	11.63	11.86	3.21	3.20	11.37	11.32	31.13	31.28
10:02:50	3.54	11.63	11.86	3.29	3.20	11.64	11.32	30.41	31.28
10:03:50	3.54	11.63	11.86	3.29	3.20	11.64	11.32	30.41	31.28
10:04:50	3.54	11.63	11.86	3.21	3.20	11.37	11.32	31.13	31.28
10:05:50	3.54	11.63	11.86	3.29	3.27	11.64	11.57	30.41	30.58
10:06:50	3.54	11.63	11.86	3.21	3.27	11.37	11.57	31.13	30.58
10:07:50	3.54	11.52	11.86	3.30	3.27	11.67	11.57	30.32	30.58
10:08:50	3.54	11.40	11.75	3.31	3.20	11.71	11.34	30.23	31.21
10:09:50	3.54	11.40	11.63	3.31	3.21	11.71	11.37	30.23	31.13
10:10:50	3.54	11.40	11.63	3.31	3.29	11.71	11.64	30.23	30.41
10:11:50	3.54	11.29	11.63	3.40	3.29	12.02	11.64	29.44	30.41
10:12:50	3.54	11.29	11.86	3.47	3.12	12.30	11.05	28.79	32.03
10:13:50	3.54	11.97	12.77	2.97	2.60	10.50	9.19	33.71	38.53
10:14:50	3.54	13.11	14.03	2.46	2.24	8.72	7.94	40.59	44.57
10:15:50	3.54	14.03	15.09	2.57	2.31	9.09	8.19	38.94	43.23
10:16:50	3.54	15.21	16.41	2.96	3.03	10.48	10.73	33.77	32.98

APPENDIX E

E - 17

AUXILIARY VENTILATION SURVEY AT HEADING #10

				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
10:17:50	3.54	15.44	16.66	3.78	3.54	13.40	12.54	26.42	28.23
10:18:50	3.54	14.97	16.04	4.22	3.81	14.94	13.48	23.70	26.26
10:19:50	3.54	15.21	16.04	3.81	3.73	13.47	13.22	26.27	26.78
10:20:50	3.54	14.97	15.68	3.62	3.57	12.81	12.62	27.63	28.04
10:21:50	3.54	14.50	15.09	3.70	3.61	13.11	12.78	27.00	27.70
10:22:50	3.54	14.27	14.73	3.54	3.46	12.53	12.24	28.25	28.91
10:23:50	3.54	14.38	14.97	3.29	3.21	11.64	11.37	30.41	31.14
10:24:50	3.54	14.97	15.56	2.97	3.10	10.50	10.96	33.72	32.29
10:25:50	3.54	15.44	15.92	2.86	2.86	10.12	10.12	34.96	34.99
10:26:50	3.54	14.73	15.21	3.17	3.06	11.23	10.83	31.52	32.69
10:27:50	3.54	13.57	14.15	3.70	3.60	13.11	12.73	27.01	27.80
10:28:50	3.54	13.11	13.69	3.59	3.54	12.72	12.53	27.83	28.25
10:29:50	3.54	12.89	13.46	3.73	3.56	13.20	12.60	26.82	28.09
10:30:50	3.54	12.66	13.11	3.53	3.54	12.48	12.53	28.36	28.26
10:31:50	3.54	12.77	13.23	3.33	3.19	11.80	11.27	29.99	31.40
10:32:50	3.54	13.23	13.69	3.00	2.87	10.63	10.16	33.31	34.83
10:33:50	3.54	13.23	13.69	3.00	2.87	10.63	10.16	33.31	34.83
10:34:50	3.54	12.66	13.23	3.28	3.24	11.61	11.48	30.49	30.82
10:35:50	3.54	12.20	12.66	3.45	3.40	12.20	12.05	29.02	29.37
10:36:50	3.54	11.97	12.32	3.47	3.50	12.28	12.39	28.82	28.58

APPENDIX E

E - 18

AUXILIARY VENTILATION SURVEY AT HEADING #10

				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
10:37:50	3.54	11.86	12.32	3.55	3.50	12.56	12.39	28.17	28.58
10:38:50	3.54	11.86	12.32	3.48	3.24	12.32	11.46	28.72	30.89
10:39:50	3.54	11.86	12.32	3.48	3.50	12.32	12.39	28.72	28.58
10:40:50	3.54	11.86	12.32	3.34	3.24	11.83	11.46	29.92	30.89
10:41:50	3.54	11.86	12.09	3.34	3.32	11.83	11.76	29.92	30.10
10:42:50	3.54	11.86	12.32	3.41	3.24	12.08	11.46	29.31	30.89
10:43:50	3.54	11.97	12.54	3.40	3.35	12.04	11.86	29.40	29.83
10:44:50	3.54	11.97	12.32	3.19	3.10	11.29	10.97	31.35	32.26
10:45:50	3.54	11.86	12.09	3.34	3.32	11.83	11.76	29.92	30.10
10:46:50	3.54	11.75	12.09	3.35	3.25	11.86	11.52	29.83	30.74
10:47:50	3.54	11.75	12.09	3.42	3.25	12.12	11.52	29.21	30.74
10:48:50	3.54	11.75	12.09	3.35	3.25	11.86	11.52	29.83	30.74
10:49:50	3.54	11.63	11.97	3.44	3.47	12.16	12.28	29.11	28.82
10:50:50	3.54	11.63	11.86	3.29	3.27	11.64	11.57	30.41	30.58
10:51:50	3.54	11.63	11.97	3.21	3.19	11.37	11.29	31.13	31.35
10:52:50	3.54	11.63	11.97	3.29	3.26	11.64	11.54	30.41	30.66
10:53:50	3.54	11.63	11.86	3.21	3.20	11.37	11.32	31.13	31.28
10:54:50	3.54	11.63	11.97	3.29	3.19	11.64	11.29	30.41	31.35
10:55:50	3.54	11.63	11.97	3.21	3.26	11.37	11.54	31.13	30.66

APPENDIX E

E - 19

AUXILIARY VENTILATION SURVEY AT HEADING #10

				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
10:56:50	3.54	11.75	12.20	3.13	2.89	11.07	10.22	31.96	34.65
10:57:50	3.54	11.97	12.54	3.12	2.95	11.03	10.45	32.09	33.87
10:58:50	3.54	11.97	12.32	3.33	3.50	11.79	12.39	30.01	28.58
10:59:50	3.54	11.86	12.09	3.34	3.39	11.83	12.00	29.92	29.49
11:00:50	3.54	11.86	12.09	3.20	3.11	11.32	11.01	31.28	32.14
11:01:50	3.54	11.75	11.97	3.28	3.33	11.61	11.79	30.50	30.01
11:02:50	3.54	11.63	11.86	3.36	3.55	11.90	12.56	29.74	28.17
11:03:50	3.54	11.52	11.75	3.45	3.56	12.20	12.61	29.00	28.06
11:04:50	3.54	11.52	11.75	3.37	3.35	11.94	11.86	29.64	29.83
11:05:50	3.54	11.52	11.75	3.37	3.42	11.94	12.12	29.64	29.21
11:06:50	3.54	11.52	11.63	3.22	3.44	11.40	12.16	31.05	29.11
11:07:50	3.54	12.32	12.77	2.81	2.74	9.95	9.70	35.58	36.50
11:08:50	3.54	13.11	13.92	2.54	2.37	8.97	8.39	39.44	42.19
11:09:50	3.54	13.69	14.27	2.49	2.39	8.82	8.46	40.14	41.85
11:10:50	3.54	14.50	14.97	2.46	2.54	8.72	8.98	40.61	39.40
11:11:50	3.54	16.29	17.28	2.11	1.97	7.46	6.97	47.44	50.80
11:12:50	3.54	18.70	20.34	1.97	1.85	6.98	6.56	50.72	53.93

APPENDIX E

E - 20

AUXILIARY VENTILATION SURVEY AT HEADING #10

				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
11:13:50	3.54	19.10	20.34	2.66	2.49	9.42	8.82	37.59	40.13
11:14:50	3.54	17.79	18.84	3.27	3.03	11.57	10.72	30.58	33.01
11:15:50	3.54	16.41	17.28	3.56	3.47	12.59	12.29	28.11	28.81
11:16:50	3.54	15.56	16.04	3.57	3.62	12.65	12.81	27.98	27.63
11:17:50	3.54	14.97	15.44	3.53	3.50	12.50	12.39	28.31	28.58
11:18:50	3.54	14.50	14.97	3.52	3.53	12.47	12.50	28.39	28.31
11:19:50	3.54	14.15	14.62	3.50	3.42	12.39	12.10	28.56	29.24
11:20:50	3.54	13.80	14.38	3.43	3.34	12.13	11.81	29.18	29.96
11:21:50	3.54	13.69	14.15	3.22	3.20	11.39	11.32	31.06	31.28
11:22:50	3.54	13.69	14.15	3.11	2.98	11.00	10.55	32.19	33.55
11:23:50	3.54	13.69	14.15	2.93	2.87	10.38	10.15	34.11	34.87
11:24:50	3.54	13.00	13.69	3.20	2.93	11.32	10.38	31.28	34.11
11:25:50	3.54	11.75	12.54	3.96	3.54	14.00	12.52	25.28	28.27
11:26:50	3.54	10.94	11.29	4.82	4.66	17.07	16.49	20.73	21.46
11:27:50	3.54	10.83	11.40	5.04	4.74	17.83	16.77	19.85	21.11
11:28:50	3.54	11.29	11.86	4.30	4.06	15.23	14.36	23.25	24.65
11:29:50	3.54	11.86	12.20	3.41	3.58	12.08	12.65	29.31	27.97
11:30:50	3.54	12.20	12.66	2.89	2.74	10.22	9.69	34.65	36.51
11:31:50	3.54	12.32	12.66	2.88	2.74	10.21	9.69	34.66	36.51
11:32:50	3.54	12.32	12.54	2.88	2.81	10.21	9.95	34.66	35.58

APPENDIX E									E - 21
AUXILIARY VENTILATION SURVEY AT HEADING #10									
				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
11:33:50	3.54	12.32	12.54	2.96	2.88	10.47	10.20	33.81	34.69
11:34:50	3.54	12.32	12.54	2.96	2.95	10.47	10.45	33.81	33.87
11:35:50	3.54	12.32	12.54	2.96	2.95	10.47	10.45	33.81	33.87
11:36:50	3.54	12.32	12.54	3.03	2.95	10.72	10.45	33.01	33.87
11:37:50	3.54	12.20	12.54	3.11	2.95	10.99	10.45	32.20	33.87
11:38:50	3.54	12.20	12.66	3.03	2.95	10.74	10.44	32.96	33.89
11:39:50	3.54	12.20	12.66	3.11	2.88	10.99	10.20	32.20	34.71
11:40:50	3.54	11.97	12.54	3.19	2.95	11.29	10.45	31.35	33.87
11:41:50	3.54	11.86	12.54	3.20	2.88	11.32	10.20	31.28	34.69
11:42:50	3.54	11.86	12.54	3.27	2.95	11.57	10.45	30.58	33.87
11:43:50	3.54	11.86	12.32	3.27	3.17	11.57	11.22	30.58	31.55
11:44:50	3.54	11.97	12.32	3.19	3.10	11.29	10.97	31.35	32.26
11:45:50	3.54	12.09	12.54	3.04	2.88	10.75	10.20	32.92	34.69
11:46:50	3.54	12.09	12.54	3.11	2.95	11.01	10.45	32.14	33.87
11:47:50	3.54	12.09	12.54	3.11	2.88	11.01	10.20	32.14	34.69
11:48:50	3.54	12.09	12.54	3.04	2.81	10.75	9.95	32.92	35.58
11:49:50	3.54	12.09	12.54	3.11	2.88	11.01	10.20	32.14	34.69
11:50:50	3.54	11.97	12.32	3.12	2.96	11.03	10.47	32.09	33.81
11:51:50	3.54	11.75	12.09	3.28	3.11	11.61	11.01	30.50	32.14

APPENDIX E

E - 22

AUXILIARY VENTILATION SURVEY AT HEADING #10

				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
11:52:50	3.54	11.63	12.09	3.29	3.04	11.64	10.75	30.41	32.92
11:53:50	3.54	11.75	12.09	3.20	3.04	11.34	10.75	31.21	32.92
11:54:50	3.54	11.86	12.09	3.12	3.04	11.05	10.75	32.03	32.92
11:55:50	3.54	11.86	12.32	3.05	2.81	10.78	9.95	32.82	35.58
11:56:50	3.54	11.75	12.32	3.20	2.88	11.34	10.21	31.21	34.66
11:57:50	3.54	11.75	12.09	3.13	2.96	11.07	10.49	31.96	33.74
11:58:50	3.54	11.75	12.09	3.13	2.96	11.07	10.49	31.96	33.74
11:59:50	3.54	11.86	12.43	2.97	2.66	10.51	9.42	33.68	37.59
12:00:50	3.54	12.54	13.34	2.51	2.19	8.88	7.74	39.84	45.76
12:01:50	3.54	13.23	13.92	2.32	2.02	8.23	7.16	43.02	49.43
12:02:50	3.54	12.89	13.23	2.60	2.54	9.20	8.99	38.48	39.37
12:03:50	3.54	12.32	12.54	3.03	2.95	10.72	10.45	33.01	33.87
12:04:50	3.54	12.20	12.54	3.11	3.02	10.99	10.70	32.20	33.09
12:05:50	3.54	11.97	12.32	3.33	3.24	11.79	11.46	30.01	30.89
12:06:50	3.54	11.97	12.77	3.19	2.81	11.29	9.95	31.35	35.58
12:07:50	3.54	11.97	13.00	3.12	2.74	11.03	9.71	32.09	36.47
12:08:50	3.54	11.86	12.32	3.20	3.03	11.32	10.72	31.28	33.01
12:09:50	3.54	11.75	12.09	3.13	3.04	11.07	10.75	31.96	32.92
12:10:50	3.54	11.63	11.97	3.21	3.12	11.37	11.03	31.13	32.09

APPENDIX E

E - 23

AUXILIARY VENTILATION SURVEY AT HEADING #10

				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
12:11:50	3.54	11.63	11.86	3.14	3.20	11.10	11.32	31.90	31.28
12:12:50	3.54	11.63	11.75	3.21	3.35	11.37	11.86	31.13	29.83
12:13:50	3.54	11.40	11.63	3.31	3.51	11.71	12.41	30.23	28.51
12:14:50	3.54	11.29	11.63	3.40	3.36	12.02	11.90	29.44	29.74
12:15:50	3.54	11.63	12.54	3.14	2.74	11.10	9.69	31.90	36.53
12:16:50	3.54	12.20	13.69	2.65	1.92	9.40	6.80	37.67	52.05
12:17:50	3.54	12.77	13.92	2.37	1.88	8.38	6.64	42.23	53.31
12:18:50	3.54	13.23	14.03	2.02	1.66	7.14	5.89	49.54	60.11
12:19:50	3.54	13.23	13.80	2.10	1.86	7.42	6.58	47.68	53.76
12:20:50	3.54	13.11	13.69	2.16	2.00	7.66	7.07	46.23	50.08
12:21:50	3.54	13.23	13.92	2.17	1.95	7.70	6.90	45.99	51.28
12:22:50	3.54	13.34	14.15	1.95	1.68	6.92	5.96	51.18	59.44
12:23:50	3.54	13.00	14.03	2.15	1.74	7.62	6.16	46.48	57.44
12:24:50	3.54	12.43	13.80	2.88	2.23	10.21	7.88	34.68	44.93
12:25:50	3.54	12.43	13.92	2.88	2.17	10.21	7.67	34.68	46.18
12:26:50	3.54	12.20	13.34	2.81	2.33	9.95	8.26	35.58	42.86
12:27:50	3.54	11.86	13.11	2.81	2.24	9.95	7.93	35.58	44.63
12:28:50	3.54	12.09	13.57	2.49	1.66	8.80	5.89	40.23	60.07
12:29:50	3.54	11.97	13.23	2.56	1.86	9.08	6.57	38.99	53.87

APPENDIX E

E -24

AUXILIARY VENTILATION SURVEY AT HEADING #10

				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
12:30:50	3.54	12.09	13.69	2.57	1.68	9.10	5.96	38.92	59.35
12:31:50	3.54	12.54	14.15	2.19	1.45	7.74	5.12	45.76	69.15
12:32:50	3.54	12.43	13.69	2.26	1.68	7.99	5.96	44.28	59.35
12:33:50	3.54	12.20	13.57	2.32	1.58	8.22	5.60	43.04	63.24
12:34:50	3.54	12.20	13.57	2.32	1.58	8.22	5.60	43.04	63.24
12:35:50	3.54	12.32	13.69	2.33	1.68	8.26	5.96	42.86	59.35
12:36:50	3.54	12.43	14.15	2.34	1.53	8.29	5.40	42.70	65.51
12:37:50	3.54	12.32	13.57	2.16	1.58	7.65	5.60	46.29	63.24
12:38:50	3.54	12.77	13.80	1.96	1.54	6.93	5.46	51.08	64.86
12:39:50	3.54	13.92	15.09	1.48	1.24	5.25	4.40	67.48	80.41
12:40:50	3.54	15.32	16.53	1.44	1.43	5.08	5.06	69.64	70.02
12:41:50	3.54	17.53	18.97	1.56	1.61	5.52	5.69	64.08	62.24
12:42:50	3.54	18.84	19.92	1.89	1.91	6.68	6.78	53.00	52.23
12:43:50	3.54	17.92	18.97	2.60	2.42	9.22	8.57	38.39	41.32
12:44:50	3.54	16.53	17.41	3.03	2.89	10.72	10.24	33.01	34.56
12:45:50	3.54	16.04	16.78	2.95	2.85	10.44	10.10	33.90	35.03
12:46:50	3.54	15.68	16.66	2.81	2.58	9.95	9.14	35.58	38.74
12:47:50	3.54	15.09	16.53	2.81	2.33	9.95	8.26	35.58	42.86
12:48:50	3.54	14.62	15.92	2.81	2.46	9.95	8.71	35.58	40.62

APPENDIX E

E - 25

AUXILIARY VENTILATION SURVEY AT HEADING #10

				MONITOR CONCENTRATION					
	Actual	Effic. of System		Purging Time		Purging Qnty (1min) &&		Effic. of System	
TIME	Quantity	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
(hr.)	(m^3/s)	(min.)	(min.)	(min.)	(min.)	(m^3/s)	(m^3/s)	(%)	(%)
12:49:50	3.54	14.15	14.97	2.75	2.54	9.74	8.98	36.34	39.40
12:50:50	3.54	13.80	14.62	2.81	2.47	9.95	8.73	35.58	40.52
12:51:50	3.54	13.69	14.50	2.75	2.52	9.73	8.93	36.38	39.64
12:52:50	3.54	14.03	14.85	2.44	2.11	8.64	7.48	40.96	47.31
12:53:50	3.54	14.38	15.32	2.20	1.91	7.80	6.75	45.37	52.47
12:54:50	3.54	14.27	15.32	2.19	1.91	7.77	6.75	45.56	52.47
12:55:50	3.54	13.80	14.73	2.36	2.17	8.36	7.67	42.32	46.14
12:56:50	3.54	13.34	14.38	2.61	2.40	9.25	8.48	38.28	41.74
12:57:50	3.54	12.89	14.03	2.74	2.31	9.70	8.18	36.48	43.27
12:58:50	3.54	12.66	13.46	2.88	2.55	10.20	9.02	34.71	39.23
12:59:50	3.54	12.54	13.46	2.88	2.55	10.20	9.02	34.69	39.23
13:00:50	3.54	12.32	13.00	3.03	2.81	10.72	9.95	33.01	35.58
13:01:50	3.54	12.43	13.00	2.81	2.60	9.95	9.21	35.58	38.42
13:02:50	3.54	12.54	13.46	2.81	2.34	9.95	8.29	35.58	42.72
13:03:50	3.54	12.43	13.23	2.81	2.54	9.95	8.99	35.58	39.37
13:04:50	3.54	12.20	13.34	2.89	2.26	10.22	8.00	34.65	44.25
13:05:50	3.54	11.86	13.57	3.20	2.28	11.32	8.06	31.28	43.90
Average	3.54	12.83	13.47	3.09	2.91	10.95	10.32	33.43	36.39
Standard Dev.	0.00	1.61	1.82	0.52	0.65	1.83	2.29	6.92	10.05

- Dilution from Pure Methane Concentration at face down to Return Air Concentration

&& - Dilution from Face Monitor Concentration to Return Air Concentration within 1 minute

APPENDIX F F - 1

RESULTS OF PAST AUXILIARY VENTILATION SURVEYS AT VARIOUS HEADINGS IN MINE #3

Date		Nov. 22, 1990	Nov. 30, 1990	Dec. 5, 1990	Dec. 13, 1990	Dec. 17, 1990
Working Place		**Heading #3**	**Heading #3**	**Heading #3**	**Heading #3**	**Heading #3**
Intake	(cfm)	6611	n/a	6866	6908	7014
Face	(cfm)	3917	n/a	4026	n/a	n/a
Return	(cfm)	4937	n/a	4429	4259	4238
Intake	(m^3/s)	3.12	n/a	3.24	3.26	3.31
Return	(m^3/s)	2.33	n/a	2.09	2.01	2.00
Face Conc.	(%)	0.24	0.31	0.40	0.74	0.19
Return Conc.	(%)	0.17	0.25	0.24	0.25	0.12
Distance from Face	(m)	3.00	16.00	10.00	12.00	19.00
Distance Outbye	(m)	60	60	60	60	60
Intake @ Face	(m^3/s)	3.06	n/a	2.17	1.76	1.09
Methane Emission	(m^3/s)	0.0087	n/a	0.0122	0.0036	-0.0047
Purging Time##	(min.)	1.41	n/a	2.94	7.69	5.25

Date		June 25, 1991	March 18, 199	April 1, 1992	June2, 1994
Working Place		Heading #3	Heading #5	Heading #5	Heading #8
Intake	(cfm)	4556	8050	8730	7605
Face	(cfm)	5650	n/a	5890	n/a
Return	(cfm)	4260	n/a	5980	7935
Intake	(m^3/s)	2.15	3.80	4.12	3.59
Return	(m^3/s)	2.01	n/a	2.82	3.74
Face Conc.	(%)	0.56	0.28	0.23	0.44
Return Conc.	(%)	0.27	0.24	0.12	0.37
Distance from Face	(m)	18.00	20.00	12.00	20.00
Distance Outbye	(m)	60	60	60	60
Intake @ Face	(m^3/s)	1.03	1.14	2.35	1.08
Methane Emission	(m^3/s)	0.0043	0.0293	-0.0064	0.0338
Purging Time##	(min.)	8.82	1.49	3.46	2.01

n/a - Not available

- Purging to the Methane concentration in the Return Air

APPENDIX G				G - 1	
LIGHT BULB TESTS AT HEADING Nos. 9 TO 11					
HEADING #9		HEADING #10		HEADING #11	
LIGHT BULB		LIGHT BULB		LIGHT BULB	
Bkground1	0.02	Bkground1	0.35	Bkground1	0.00
Bkground2	0.00	Bkground2	0.50	Bkground2	0.00
Time (s)	SF_6 conc. (ppb)	Time (s)	SF_6 conc. (ppb)	Time (s)	SF_6 conc. (ppb)
0	0.00	0	0.16	0	0.00
15	0.02	15	1108	15	0.25
30	11.02	30	285.84	30	381.60
45	6.06	45	184.29	45	305.30
60	4.34	60	160.27	60	265.20
90	2.40	75	112.59	75	265.90
120	1.04	90	90.29	90	183.20
150	0.55	105	79.41	105	176.70
180	0.30	120	66.77	120	145.60
210	0.17	135	63.4	135	115.30
240	0.12	150	57.79	150	102.10
270	0.08	165	53.51	165	88.20
300	0.05	180	47.39	180	84.80
		195	44.11	195	73.80
		210	39.61	210	62.40
		225	37.39	225	54.20
		240	33.94	240	52.50
		255	32.16	255	44.30
		270	31.84	270	40.50
		285	29.62	285	35.70
		300	26.64	300	31.80
		330	23.31	330	24.10
		360	19.67	360	20.30
		390	16.94	390	16.00
		420	14.49	420	14.30
		450	12.72	450	10.90
		480	12.34	480	8.79
		510	10.01	510	6.95